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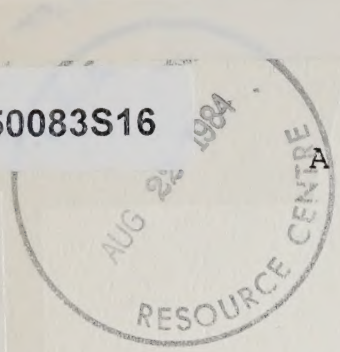

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A SAFETY AND RELIABILITY ANALYSIS OF ARCTIC PETROLEUM PRODUCTION AND TRANSPORTATION SYSTEMS - A PRELIMINARY STUDY

Volume 2 - Appendices A & B

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A SAFETY AND RELIABILITY ANALYSIS OF ARCTIC PETROLEUM PRODUCTION AND TRANSPORTATION SYSTEMS - A PRELIMINARY STUDY

Volume 2 - Appendices A & B

by

FENCO CONSULTANTS LIMITED
Calgary, Alberta

This report is the result of a contract let under a spill prevention/contingency planning program of the Environmental Impact Control Directorate. Contributory funding was also provided by DIAND, DOT/DRSS and EMR/CANMET. This unedited version is undergoing a limited distribution to transfer the results to people working in related studies.

The report has not undergone rigorous technical review by the Environmental Impact Control Directorate, or any of the other funding agencies, and it does not necessarily reflect the views and policies of Environment Canada or these other agencies.

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Environmental Emergency Program Division
Waste Management Branch
Environmental Protection Service
Environment Canada
Ottawa, Ontario
K1A 1C8

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APPENDIX A

ENVIRONMENTAL CONSEQUENCES OF HYDROCARBON SPILLS

APPENDIX A

ENVIRONMENTAL CONSEQUENCES OF HYDROCARBON SPILLS

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APPENDIX A

A. ENVIRONMENTAL CONSEQUENCES OF HYDROCARBON SPILLS

A.1 Introduction

The goal of the study was to identify the risk to the arctic environment posed by oil spills likely to result from production and transportation of hydrocarbons. The analysis in the engineering sections identified likely transportation corridors and activity centres throughout the Arctic and northeastern Canada, and showed different levels of probability of occurrence of different sized oil spills. In this preliminary biological impact analysis, it is not feasible to provide a detailed evaluation of each of those spill sizes in all areas. Spill drift trajectories and water column dispersions were evaluated for spills of 30, 300, 3,000 and 30,000 m^3.

In considering small spills, the level of detail of available biological information does not permit site-specific identification of impacts. Generally speaking, 30 m^3 spills should have very localized effects, even though they may be the most frequent type of spill.

In confined areas without good flushing, chronic spillage could permanently degrade the local aquatic environment. Spills of 300 and 3,000 m^3 would likely have similar effects on a proportionately larger scale. The decreased frequency with which these spills are likely to take place means that short-term effects may be more prevalent than chronic ones. Spilled oil from single accidents can, however, be incorporated into sediments and then be released to pose a chronic exposure to surrounding biota.

Environmental impacts have been assessed for spills of 30,000 m^3 which were identified as the maximum probable spills for both blowouts and tanker losses. Spills were assumed to be of short duration and therefore the results are generally applicable to tanker loss. In the case of blowouts, the impacts become less predictable as the spill duration increases, especially if it extends beyond the ice-free season.

The adequacy of the environmental data bases was evaluated. Weaknesses in the data bases were identified, and recommendations were made for future research. Specifically excluded from the scope of the study were non-spill related effects resulting from production/transportation activities in the Arctic, such as disturbances to mammals or alterations in ice dynamics from the passage of tankers.

Nine potential spill sites were selected, and these are discussed in the following section.

Predictions of spilled oil trajectories, potential slick sizes and portions of the water column affected by oil were made for each site. This critical information for impact predictions incorporated the limited surface current and wind data available. Maps of drift trajectories and water column dispersions for spills of 30, 300, 3,000 and 30,000 m^3 are found in Appendix B.

Analysis of biological resource data resulted in resource descriptions of varying degrees of completeness. Available site-specific information was plotted on a series of resource maps for each area and these are found in Appendix B. The major resource groups considered were: plankton and invertebrates; fish; birds (seabirds and waterfowl) and marine mammals. Hunting and fishing are identified as resource utilization. The lack of information is obvious on many maps and on others single values may give an illusion of available information. For example, what may appear as concentrations of primary production more likely indicate that data exist for only that site. Where possible, extrapolations have been made from site-specific data, but in some cases, basic site-specific data were unavailable.

The following sections (A.2 to A.5.1) discuss the methodology as it applies to all of the sites. Sections A.5.2 to A.5.9 discuss the specific sites and impacts. The impacts for all sites are summarized in Table A.2 for a spill of 30,000 m^3.

A.2 Site Selection and Data Collection

A.2.1 Site Selection

The approach for the collection of data and the identification of data gaps was to perform a series of area-specific "mini-impact" analyses. By choosing a number of potential spill sites, it is possible to deal with environmental data in a more objective and systematic manner then would have been possible for a study of the entire area.

The environmental effects of hydrocarbon spills associated with production or transportation of petroleum hydrocarbons were evaluated at nine sites throughout the Arctic and down the Labrador coast (Table A.1, Figure 1-2). The sites were chosen after an examination of environmental information for the entire Arctic, consideration of the likely transportation routes for petroleum hydrocarbons, and areas of proven or potential hydrocarbon reserves that may be sites for production facilities. Possible production areas currently identified are the Beaufort Sea, the Sverdrup Basin and the Labrador Sea. Major marine transportation corridors where spills could occur have been described in Section 2.3.

Two potential spill sites were chosen for the Beaufort Sea. Site 1 is near-shore, at the location of the ADGO F-28 wellsite off Garry Island. Site 2 is offshore at a mid-point between the Tarsuit A-25, Nektoralik K-29 and Kopanoar M-13 wellsites. Two sites have been chosen for this region because of the differences in on- and offshore current patterns, ice regimes and biological resources.

Armstrong Point in the Prince of Wales Strait was chosen as Site 3 for a spill. This site represents a relatively confined portion of the middle Arctic.

Site 4 was designated in Viscount Melville Sound. This area might receive not only through tanker traffic but also traffic in and out of any potential shore-based stations, e.g., Bridport Inlet.

TABLE A.1

DESIGNATED SPILL SITES FOR THE EVALUATION OF OIL SPILL IMPACTS

SITE NO.	LOCATION	DESCRIPTION NAME
1	69°25'N, 136°W	Nearshore Beaufort Sea
2	70°12'N, 135°W	Offshore Beaufort Sea
3	73°N, 122°30'W	Armstrong Point (Prince of Wales Strait)
4	74°40'N, 105°W	Viscount Melville Sound
5	77°20'N, 102°30'W	Sverdrup Basin
6	75°N, 99°38'W	Allison Inlet
7	74°37'N, 91°13'W	Cape Liddon
8	74°6'N, 80°22'W	Cape Hay (Lancaster Sound)
9	55°29'N, 57°30'W	Cape Harrison (Labrador Sea)

Site 5 was chosen in the Sverdrup Basin south of Ellef Ringnes Island as a potential spill site. Current industry exploration activity is directed to this area. A spill site was therefore chosen for this geographical region.

A currently favoured scenario for the export of petroleum products extracted in the Sverdrup Basin would involve transportation south by pipeline across Bathurst Island to Allison Inlet or the south coast for transfer to tankers. Site 6 was chosen to provide for coverage of accidents in this region. Ships carrying crude oil from further west would also pass through this area and would likely use terminal facilities along the way for minor repair or crew transfer or even product cargo transfer.

The waters off Cape Liddon in the Barrow Strait were chosen as Site 7. This area is adjacent to Lancaster Sound and is of note because the westward-retreating spring ice edge passes through this area.

Site 8 was chosen in Lancaster Sound midway between Cape Hay and Cape Warrender. As one of the acknowledged areas of major biological importance in the Canadian Arctic, Lancaster Sound was a necessary choice for inclusion in this study.

Site 9 is located in the Labrador Sea off Cape Harrison. This site is in an area of active oil exploration and lies along the projected shipping lanes for transport of oil from the Canadian Arctic to southern refineries and markets.

A.2.2 Data Collection

Data collection efforts were focused on marine environmental surveys with a broad scope or which synthesized descriptive studies. Site-specific descriptions of flora and fauna were not emphasized in searches although they were included when readily available.

Data gathering was aided by a computer literature search of several bibliographic data bases, review of personal holdings of project staff, interviews with industry scientists, review of government research reports and studies,

and previous impact assessments for portions of the Canadian Arctic and the Labrador Coast.

A.3 Impact Evaluation Procedures

The marine environmental data obtained during the data gathering phase of the project were classified by geographic site and the following categories: plankton and invertebrates, seabirds and waterfowl, marine mammals, fishery resources, and hunting and fishing. For impact evaluation purposes, resources were analysed on the basis of a year divided into two seasons: open-water and ice-covered. Resources were then catalogued by each of these seasons.

Oil spill spreading calculations and projected directions were next reviewed for each site for spills of 30, 300, 3,000 and 30,000 m^3. Point-by-point evaluations of probable levels of effect from a 30,000 m^3 oil spill on each biological resource for each season were performed. Impact levels were based on a five-category classification system. These categories and their definitions (derived from the Davis Strait EIS, Imperial Oil Ltd. et al, 1978) are:

A Major Impact affects a whole population or species in sufficient magnitude to cause a decline in abundance and a change in distribution beyond which natural recruitment (reproduction and immigration from unaffected areas) would not return that population or species, or any population or species dependent upon it to its former level within several generations. In some instances, with respect to resource use by humans, an impact may not satisfy the above conditions, but nevertheless results in significant effects on the human user. Thus, a major impact may also be classified as that affecting a subsistence or commercial activity such that the well-being of the user is affected.

A Moderate Impact affects a portion of a population and may result in a change in abundance and distribution over one or more generations of that portion of the population or any population dependent upon it, but does not change the integrity of any population as a whole. It may be localized.

A Minor Impact affects a specific group of individuals of a population at a localized area and over a short time period (one generation or less), but does not affect other trophic levels or the integrity of the population itself.

A Negligible Impact has no significant or measureable effect.

An Insufficient Information designation connotes that either the data base is insufficient to permit a reasonable assessment of impact level, or that the impact level designation should be considered tentative because it was made with a limited knowledge of the resource or oil behavior.

A.4 Models of Slick Movement

A.4.1 Procedure

The ultimate fate of oil spilled on the sea surface is determined by a complex interaction of physical, chemical and biological processes. The major mechanisms which are usually identified in slick movement models are spreading, advection, evaporation, dispersion and dissolution. Although these mechanisms are defined there is still a great deal unknown about their interactions and their dependence on the many environmental variables involved.

In order to model slick movement, much information is required about the physical environment and the characteristics of the spilled oil. The environmental data for Arctic regions are sparse, and the properties of the oil are not fully known. It would be inappropriate to attempt to predict the fate of spilled oil to any greater accuracy than these sparse data permit.

The attributes of an oil spill which are of primary concern to the assessment of risk from a biological point of view are the physical extent and duration of the surface slick, the extent and concentration of oil levels in the water column and the degree of benthic contamination.

The method used here is a first order analysis of maximum surface extent and the associated water column concentrations and is based on conservative assumptions to give a worst-case design spill. These results are then applied to each study and interpreted in terms of the available oceanographic and meteorological data.

Surface Extent

The most widely accepted formulation for the spreading of oil on the sea surface is based on the work of Fay (1977). Spreading is presented as consisting of three sequential regimes which reflect force balances of oil inertia and gravity (inertial spreading), oil viscosity and gravity (viscous spreading), and oil viscosity and surface tension (surface tension spreading). The final surface tension regime predicts spreading to a monomolecular thickness. Observations indicate that this does not occur; rather spreading usually ceases at a thickness of 10^{-2} to 10^{-3} cm. Fay suggests a mechanism for cessation of spreading, which with typical values for oil properties and environmental conditions yields a rule of thumb for maximum surface extent:

$$A = 10^5 V^{3/4}$$

where A is the slick area in m^2 and V is the total volume of the slick in m^3. The work of Fay is reasonably rigorous in addressing the physics of spreading with the assumptions that the oil is homogeneous, its properties are constant with time and that it is spreading on a quiescent fluid; (i.e., there is no turbulence or shear caused by winds or currents).

It has been observed in field studies that in fact oil on the sea does not spread as a homogeneous fluid but separates into thin and thick slicks with as much as 90% of the oil being in 10% of the area (MacKay and Leinonen 1977). Not much is known about the composition of the thin slick due to sampling difficulties. It is suspected that the thin slicks are at least in part the result of surface fractionation and therefore represent the less viscous, more volatile (and toxic) lower molecular weight fractions.

In an attempt to address the thin versus thick slick problem, MacKay et al (1980) use empirical relationships to describe the two-phase system. The thick slicks spread in the manner of Fay's viscous spreading regime and the thin slick spreads as a surface tension slick with a constant thickness (10^{-6} m). An exponential coupling term is included by which the thick slick is allowed to feed the thin slick as a function of the thickness of the thick slick.

These equations formulated in terms of surface area and expressed in finite difference form are:

$$\Delta A_{Tn} = (K_a)(A_{Tn})^{0.33}\, e^{\frac{-(K_c)\Delta t}{z}}$$

$$\Delta A_{Tk} = (K_b Z^{1.33})\, A_{Tk}^{0.33}\, \Delta t^{\frac{-(.000001\Delta AT_n)}{z}}$$

where

A_{Tn} = area of thin slick
Z = thickness of thick slick
Δt = time increment
ΔA_{Tn} = change in thin slick area during time increment Δt
A_{Tk} = area of thick slick
ΔATk = change in thick slick area during time increment Δt
K_a, K_b, K_c = empirical constants: taken at "typical" values

This formulation allows for a stepwise solution in time, with appropriate adjustments (if known) for losses volume and changes in properties due to evaporation, dissolution or dispersion at each time step. Though this approach is not physically rigorous, it does predict maximum areas similar to those predicted by Fay and also addresses the important thin-versus-thick slick problem.

Since an estimate of thick slick area is useful in estimating water column concentrations, this formulation has been employed. The results of these calculations for the various spill volumes are presented are Figure A-1.

These results have been used as design surface areas for the various spill sizes and are considered to be conservative.

Water Column Concentrations

Perhaps the least understood and most important aspect from a toxicity point of view is the dispersion/dissolution of oil into the water column. It is generally impossible to differentiate between the dissolved and the dispersed (in small droplets) oil in the water column. Thus, they are generally treated together and are more properly termed the Water Accommodated Fraction (WAF).

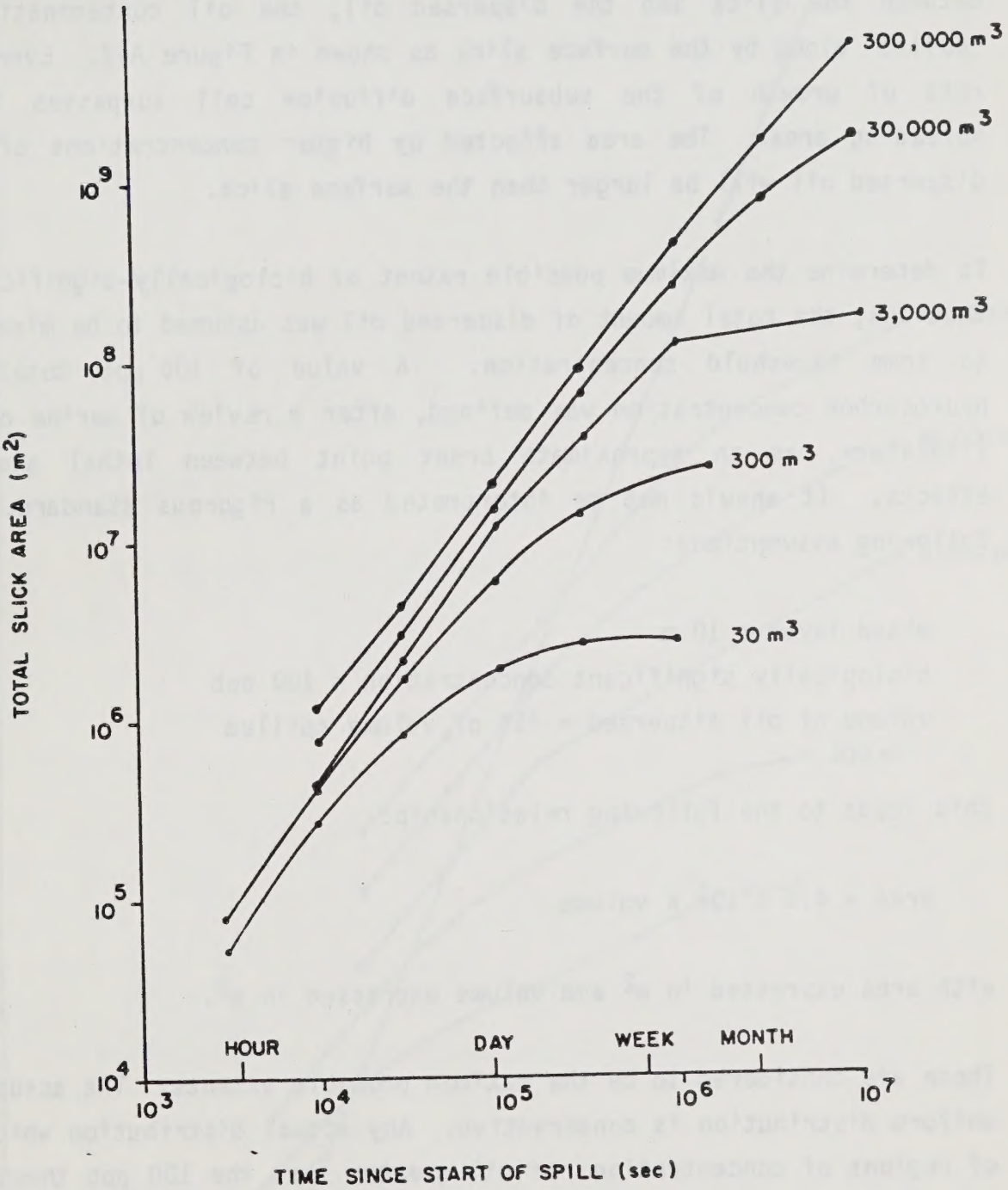
There are several formulations for determining the rate of dispersion/-dissolution, generally with major dependence on oil properties, sea state and oil thickness. Since these parameters are in general not known with the exception of the oil thickness estimate from the spreading analysis, a simpler approximation must be used. Therefore, a first order analysis has been made to express area of contamination versus time and to establish a maximum possible area of biologically-significant concentrations.

In order to determine the extent of heavily-affected water mass, comparison can be made with a point release of marked fluid. According to Okubo (1971) the length scale (radius) of a dye cloud or diffusion cell after instantaneous release can be approximated by

$$L = 0.155\ t^{1.19}$$

where L is expressed in cm and t is time in seconds.

The significant concentrations of hydrocarbon can be considered to emanate from the thick slick areas because up to 90% of the oil resides there. Also, dispersion increases with thickness and there is not enough oil in the thin



TOTAL SLICK AREA VS TIME FOR GIVEN SPILL VOLUME
(After MacKay 1981)

FIG. A-1

slick area to raise water column concentration very high (1 ppm for a 10 mm slick totally mixed in 10 m of water). This is not to say that these concentrations are not biologically significant. Initially, the rate of surface spreading is greater than the diffusion rate, and assuming no relative motion between the slick and the dispersed oil, the oil contamination will be "pulled" along by the surface slick as shown in Figure A-2. Eventually, the rate of growth of the subsurface diffusion cell surpasses the surface spreading area. The area affected by higher concentrations of submerged, dispersed oil will be larger than the surface slick.

To determine the maximum possible extent of biologically-significant concentrations, the total amount of dispersed oil was assumed to be mixed uniformly to some threshold concentration. A value of 100 ppb total petroleum hydrocarbon concentration was defined, after a review of marine oil toxicity literature, as an approximate break point between lethal and sublethal effects. It should not be interpreted as a rigorous standard. With the following assumptions:

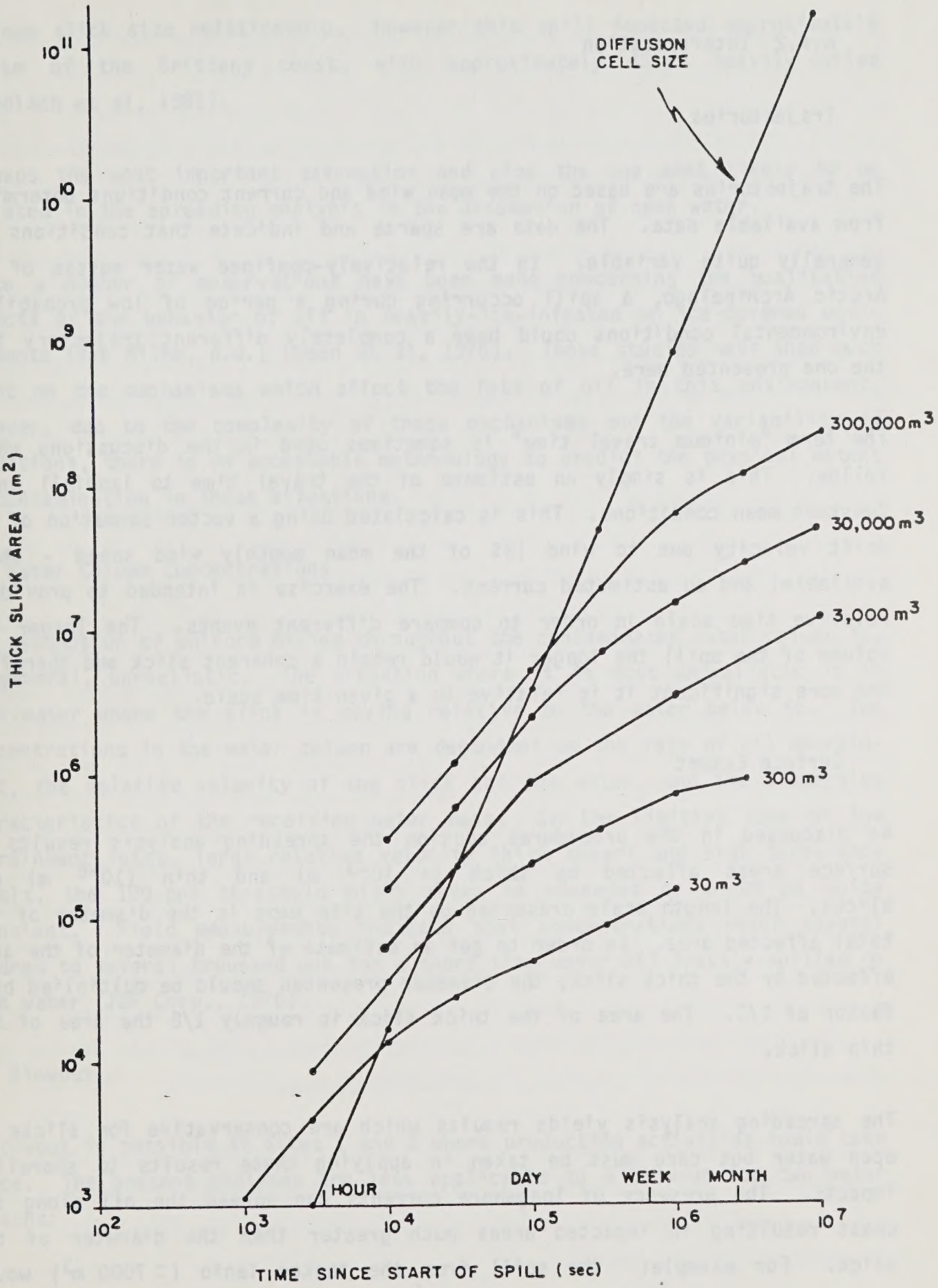
mixed layer = 10 m
biologically significant concentration = 100 ppb
volume of oil dispersed = 45% of volume spilled

this leads to the following relationship:

$$\text{area} = 4.5 \times 10^5 \times \text{volume}$$

with area expressed in m^2 and volume expressed in m^3.

These are considered to be the maximum probable extents. The assumption of a uniform distribution is conservative. Any actual distribution which consists of regions of concentrations of oil greater than the 100 ppb threshold would result in a smaller affected area.



THICK SLICK SURFACE AREA VS TIME FOR GIVEN SPILL VOLUME

FIG. A-2

A.4.2 Interpretation

Trajectories

The trajectories are based on the mean wind and current conditions determined from available data. The data are sparse and indicate that conditions are generally quite variable. In the relatively-confined water masses of the Arctic Archipelago, a spill occurring during a period of low probability environmental conditions could have a completely different trajectory than the one presented here.

The term "minimum travel time" is sometimes used in the discussions which follow. This is simply an estimate of the travel time to landfall under constant mean conditions. This is calculated using a vector summation of the drift velocity due to wind (3% of the mean monthly wind speed - where available) and an estimated current. The exercise is intended to provide a relative time scale in order to compare different events. The larger the volume of the spill the longer it would remain a coherent slick and therefore the more significant it is relative to a given time scale.

Surface Extent

As discussed in the procedures section the spreading analysis results in surface areas affected by thick ($> 10^{-3}$ m) and thin (10^{-6} m) oil slicks. The length scale presented on the site maps is the diameter of the total affected area. In order to get an estimate of the diameter of the area affected by the thick slick, the diameter presented should be multiplied by a factor of 1/3. The area of the thick slick is roughly 1/8 the area of the thin slick.

The spreading analysis yields results which are conservative for slicks on open water but care must be taken in applying these results to shoreline impacts. The presence of longshore currents can spread the oil along the coast resulting in impacted areas much greater than the diameter of the slick. For example: the spill from the tanker Tanio ($\simeq 7000$ m^3) would have resulted in a slick approximately 10 km in diameter according to Fay's

maximum slick size relationship. However this spill impacted approximately 197 km of the Brittany coast, with approximately 45 km heavily oiled (Gundlach et al, 1981).

Perhaps the most important assumption and also the one most likely to be violated in the spreading analysis is the assumption of open water.

Quite a number of observations have been made concerning the qualitative aspects of the behavior of oil in heavily-ice-infested or ice-covered environments (see Milne, n.d.; Green et al, 1976). These studies have shed much light on the mechanisms which affect the fate of oil in this environment. However, due to the complexity of these mechanisms and the variability of conditions, there is no acceptable methodology to predict the physical extent of contamination in these situations.

Water Column Concentrations

The assumption of uniform mixing throughout the contaminated water column is, in general, unrealistic. The situation where it is most unrealistic is in open water where the slick is moving relative to the water below it. The concentrations in the water column are dependent on the rate of oil entrainment, the relative velocity of the slick and the water, and the dispersive characteristics of the receiving water mass. In the limiting case of low entrainment rates, large relative velocity (high shear) and high turbulence levels, the 100 ppb threshold might never be exceeded or might be quite transient. Field measurements indicate that concentrations reach several hundred to several thousand ppb for a short time under oil freshly-spilled on open water (JBF Corp., 1976).

Blowout

A blowout is possible at Sites 1 and 2 where production activities could take place. The present analyses are less applicable to a blowout for two major reasons:

1) A blowout of this magnitude could extend into the ice covered seasons, and

2) The assumptions inherent in the spreading analysis become increasingly unrealistic over long time scales.

The effect of a blowout in the Beaufort Sea is a subject of much controversy. Estimates of the area affected by such an event cover several orders of magnitude (Greene et al, 1976, Milne, n.d., Walker, 1975). Perhaps the only point that is not controversial is that oil contamination would be extremely persistent due to the retarded weathering of oil either under or frozen into ice.

A.5 Environmental Consequences of Representative Hydrocarbon Spills

A.5.1 General Considerations and Limitations

Several basic characteristics of the biology of arctic marine populations bear upon oil impact evaluations. In the severe and strongly seasonal Arctic environment, reproductive patterns of marine invertebrate organisms have centered on brooding a few offspring, rather than relying on pelagic dispersal of large numbers of larvae where few may survive. The nurturing of offspring is followed by slow growth throughout long lifespans. The lack of planktonic larval dispersal in many species limits recruitment potential to many populations via immigration, especially for benthic species. Biological production is strongly focused around a short, intense spring at the period of ice break-up. Organic matter produced at that time is the majority of the year's production. Cycling of this matter, and perhaps of pollutants subject to trophic transfer, is through relatively shorter, simpler food chains than those associated with more temperate marine systems.

Because of the short production season, many of the animal species have only one generation per year. The spawning season is short for fish and any other species whose larvae are dependent for survival upon the food resources of the short production season.

The characteristics of the arctic environment have resulted in many species living critically close to their capacity for adapation to environmental change. Seabirds and waterfowl illustrate this point well. Most of these species migrate long distances to breed in the summer in the Arctic. Some either reach peak weight before they begin the migration or at staging areas along the way so that once they arrive at their destinations in the Arctic they can immediately breed and have offspring old enough to travel by the end of the short summer season. Without adequate food supplies in summer nesting areas, survival of the young and perhaps even the adults could be endangered. If nesting is disturbed, most bird species will not have the opportunity to re-nest because of the limited open-water season available, with the resultant loss of a year-class of birds.

The impacts discussed in this section deal only with the effects of large (30,000 m^3) oil spills from tankers or oil well blowouts. These events are rare, but have the greatest acute impact and their effects may last for years. The study does not attempt to address the potential damages from the many activities associated with petroleum exploration, development, production and transportation in the Arctic. Rated impacts on resources for all designated spill areas are presented in Table A.2.

A number of factors or data deficiencies are common to all the site-specific impact evaluations that are presented in the following sections. Ice plays the dominant role in modifying oil fate and controlling the timing of biological processes in the Arctic. In its various forms ice can:

- limit the horizontal dispersion of spilled oil;
- severely limit the effectiveness of oil spill countermeasures;
- result in the selective retention of lighter molecular weight aromatic hydrocarbon compounds when oil is in brash ice (Reimer, 1980);
- control beach processes and oil fate on intertidal areas;
- regulate the timing of biological activity by providing access to open water as ice melts or breaks up.

Arctic waters are covered by ice either partially or completely for a large proportion of the year. Thus, precise knowledge on the probable fate of oil in ice is necessary for oil impact prediction for the Arctic. Recent research results and review papers indicate that we do not presently have this level of knowledge (Environmental Protection Service, 1981; MacKay, 1981). The Kurdistan oil spill off Nova Scotia was one of the few opportunities to observe the behaviour of spilled oil in sea ice (Reimer, 1980). Without additional field monitoring data from spills of opportunity or experimental spills in sea ice, our knowledge of oil fate under those circumstances will remain imprecise.

Current understanding of the effects of oil on Arctic marine organisms is at a basic level, consisting principally of information on lethal toxicity. A smaller body of information is available on sublethal effects. (e.g., Percy, 1978; Duval and Fink, 1980; Fink, Harwood and Duval, 1981; Hutcheson and Harris, 1981). The inability to empirically relate some of the sublethal physiological effects to populations is still a hindrance to the useful application of much sublethal data. The present Baffin Island Oil Spill Program (coordinated by Environmental Protection Service, Edmonton) should provide some of the first data on population level effects of oil spills in the Arctic.

It has been particularly difficult to obtain data for the effects of oil on marine mammals. This shortcoming makes it particularly difficult to discuss the population implications of oiling of individuals. Recent controlled oiling of polar bears suggests that this species is quite sensitive to external oiling as a result of grooming activities (Englehardt, 1981). For this reason, polar bears have been given a higher impact rating than might be inferred from their fairly cosmopolitan distribution throughout the Arctic.

The biological information available for the Canadian Arctic is primarily descriptive and lacking in process oriented studies. For this reason, designations of probable environmental effects of oil at the community or ecosystem levels are not based upon empirical data but on reasonable judgement. The authors believe that there is a substantial amount of uncertainty

inherent in predicted impact levels for these levels of biological organization.

The impact classification scheme emphasizes individual species at a global level of consideration. Community and ecosystem level impacts are not easily classified by the scheme so that assigned impacts in the following sections may, in some cases, underestimate the ecosystem level of impacts. Damage causing gross depletions in populations of all animals and plants in an area might not be major if no single species population viability was threatened. However, loss of a functioning marine system which may be very important regionally could be an impact of substantial consequence. Repopulation by some species that do not show fidelity to traditional nesting, migration, staging or feeding areas may be expected, but repopulation by highly traditional species such as Lesser Snow Geese or some whales is unlikely or at best open to chance. For this reason, loss of a traditional resource in an area may not fit the working definition of a major impact used in the subsequent evaluations, but it may represent substantial area-specific alteration in community structure.

The following is a brief review of some of the sensitive environmental components found in the Arctic.

Ice edges across the mouths of sounds and bays, or leads in the spring, are the sites of large concentrations of marine mammals. Narwhal, beluga whale, walrus and harp seal may all await break-up of the ice and feed on polar cod at the ice edge. Polar bear and ringed seal may also concentrate along these ice edges in the spring for feeding.

Beluga whale may be exposed to contact with oil as a result of their assembly in bays during the calving period (July-August). They also concentrate during the fall migration.

Bowhead whales presently have a small population size (especially in the eastern Arctic) and a low replacement potential. These characteristics make the population susceptible to oilspill-related damage.

The bearded seal is another species with the same population characteristics as the bowhead. Their use of shallow coastal water for feeding during the summer ties their fate to that of nearshore benthic invertebrate populations. When concentrating in areas of moving ice where they pup in April, their chances of coming into contact with oil in leads is substantially increased.

The replacement potential of walrus is low. Since they tend to concentrate at specific coastal sites during the summer, they are vulnerable as a group to coastal oiling.

Of the marine-associated birds using the Canadian Arctic, those using the water frequently will have the greatest probability of contacting spilled oil. The alcids, (Thick-billed Murre, Puffin, Dovekie, Black Guillemot), the diving ducks (eider) and most of the seabirds could fall victim to oil damage by virtue of their feeding habits which require contact with the water, and their nesting and rearing habits that permit transfer of oil to eggs or young. Because of the large proportions of known populations using specific areas of the Canadian Arctic, the Thick-billed Murre, Northern Fulmar, Black-legged Kittiwake and Dovekie would be susceptible to population damage in the Eastern Arctic. In the western Arctic, brant and Lesser Snow Geese are quite susceptible at the population level to oiling damage because of the large percentages of these populations using the Mackenzie Bay area for staging.

The types of fish that occur at the chosen study sites in the Arctic are generally known, but specific information on relative distributions, stocks, seasonal movements and energetics is lacking. This is particularly so during the winter months. An absence of pelagic fish species and predominance of demersal and ice-associated fish characterizes most of the Arctic. Epontic production is transferred to the rest of the food chain predominantly by polar cod. Arctic char is the other high profile and cosmopolitan fish species in the Arctic. It is exempt from direct marine oiling damage to the oil sensitive egg and larval stages, which are spawned and develop in fresh water. Effects of oil on adult Arctic char are primarily conjectural and in need of further investigation.

Production activities will result in chronic but low-level types of effects on the surrounding regions. Although it is possible to identify the nature of chronic disturbances, the present level of understanding of Arctic biological processes does not permit projections of likely long-term effects. In the case of artificial islands in the Beaufort Sea, production effects may be localized and generally restricted to a loss of portion of the existing benthic community and the creation of new shallower benthic habitat around the island's perimeters.

Site by site descriptions of the probable impacts of a 30,000 m^3 oil spill upon the marine environment are presented in the following sections. The impacts are tabulated in Table A.2. Appendix B of this report contains the resource information upon which the impact evaluations were based.

A.5.2 Beaufort Sea

SITE 1: MACKENZIE BAY

SITE DESCRIPTION

This is a nearshore site located in northeast Mackenzie Bay at 69°25 N, 136°W. Water depth in this area is shallow, less than 10 m, and slopes gently to 400 m about 180 km off shore. The outflow of the Mackenzie River is an important component of the coastal environment, providing much sediment and dominating coastal currents. The coast itself is a flat low lying plain of unconsolidated sediments. The delta channels are leveed and most of the coast behind these levees and beaches is characterized by abundant shallow lakes and marshes. The outer coast is considered a sheltered wave environment with tides of less than 1 m. However storm surges of up to 3 m are known and can result in flooding of the coast behind beaches and levees.

The entire nearshore area is covered with landfast ice during the winter with a 1 to 4 month open-water season. There is a transition zone farther offshore between the landfast ice and the polar pack which is a region of open-water and refrozen leads. The amount and duration of open water along the coast in summer after the melting of the land-fast ice is controlled by the position of the polar pack, which is variable from year to year.

IMPACTS

The impacts for this site are summarized in Table A.2. Under the effect of the prevailing easterly flow of Mackenzie River water along the coast, there is a high probability of shoreline contamination. This coast is currently undergoing active erosion which may tend to bury the oil in the sediments, but is more biologically sensitive than other Arctic coasts included in this study because of its importance to birds.

Oil contamination from a blowout would be more serious than a single spill because the longer time of discharge would allow the oil to move in a greater variety of directions under the influence of a range of weather conditions.

TABLE A.2

SUMMARIZED BIOLOGICAL IMPACTS AT SELECTED CANADIAN ARCTIC SPILL SITES FOR THE ICE-FREE AND ICE COVERED SEASONS

Impact Levels: M - Major; M - Moderate; m - Minor; n - Negligible; I - Insufficient Data to Make Evaluation (e.g., M/I = Moderate and/or Insufficient Data)

	RECEPTOR				
SITE	PLANKTON/ INVERTEBRATES	MARINE MAMMALS	SEABIRDS	FISHERY RESOURCES	RESOURCE UTILIZATION
1 - Mackenzie Bay - Open Water	m (phyto- and zooplankton) m/M (zoobenthos)	n/m (polar bear) M/I (beluga, bowhead) M (ringed and bearded seals)	M/ M (all species)	m (cod and flounder) M (whitefish, herring char, capelin)	m/M (hunting) M (fishing)
- Ice-Cover	m (all groups)	M/I (polar bear, ringed and bearded seals)	m/M/ M (all species)	m (cod and flounder) m/ M (whitefish, herring, char, capelin)	n (hunting and fishing)
2 - Beaufort Sea - Open Water	m (phyto- and zooplankton) m/M (zoobenthos)	n/m (polar bear) m/M/I (beluga) M /I (bowhead) M (ringed and bearded seals)	m/M/I (all species)	m (cod and flounder) I/m/M (all others)	m/M (hunting and fishing)
- Ice-Cover	n (zoobenthos) m (phyto- and zooplankton)	M/I (polar bear, ringed and bearded seals)	n/M/ M (all species)	m (cod and flounder) m/M (others)	n (hunting and fishing)
3 - Armstrong Point - Open Water	I (all groups)	m/I (bowhead, beluga, and ringed seal)	M/ M (King Eider, Oldsquaw) I (river nesters)	m (polar cod) M (char)	n (hunting) m (fishing)

TABLE A.2 (CONT'D.)

SITE	RECEPTOR: PLANKTON/ INVERTEBRATES	MARINE MAMMALS	SEABIRDS	FISHERY RESOURCES	RESOURCE UTILIZATION
- Ice-Cover	I (all groups)	m/I (polar bear, ringed seal)	M/ M (King Eider, Oldsquaw spring only I (river nesters)	m (polar cod) M (char, spring only)	m (hunting) n/m (fishing)
4 - Viscount Melville Sound - Open Water	m/I (all groups)	m (seals) m/M (polar bear)	m/I (all species)	m (all species)	n (hunting and fishing)
- Ice-Cover	m/I (all groups)	m (seals, polar bear)	n/m/I (all species)	n/m (all species)	n (hunting and fishing)
5 - Sverdrup Basin - Open Water	I (all groups)	m/M/I (polar bear, walrus)	I (Glaucous Gull, brant) m/ M (Ivory Gull)	m/I (all species)	n (hunting and fishing)
- Ice-Cover	I (all groups)	m/M/I (polar bear, walrus)	n (all species)	m/I (all species)	n (hunting and fishing)
6 - Allison Inlet - Open Water	m/I (all groups)	m (bearded seal) M/I (polar bear, ringed seal, and walrus)	m to M/I at Ice Edge (all species)	I (all species)	M/ M (hunting) M (fishing)
- Ice-Cover	n/I (all groups)	m (bearded seal) m/I (ringed seal) M (walrus, polar bear) n/m (all others)	n to M at Ice Edges and Leads (all species)	I (all species)	M/ M (hunting) n (fishing)

TABLE A.2 (CONT'D.)

SITE	RECEPTOR: PLANKTON/ INVERTEBRATES	MARINE MAMMALS	SEABIRDS	FISHERY RESOURCES	RESOURCE UTILIZATION
7 - Cape Liddon - Open Water	m to M in Localized Areas (all groups)	m (bearded seal) M (polar bear, narwhal, walrus and ringed seal) M/ M (beluga and bowhead)	M (murres and Northern Fulmar)	I (all species)	m/M (hunting) n/m (fishing)
- Ice-Cover	n/m (all groups)	m (bearded seal) M (polar bear)	n/M (all species) M (all species, spring only)	I (all species)	m/M (hunting) n/m (fishing)
8 - Cape Hay - Open Water	M (all groups)	n/m (polar bear) m (walrus) m/I (seals) M (beluga, narwhal) M/ M (bowhead)	M (Thick-billed Murre, Northern Fulmar, Black-legged Kittiwake, Dovekies)	n/m (char) M (polar cod)	M (hunting) n (fishing)
- Ice Cover	m (all species) M (all groups, spring only)	n (narwhal, walrus, bowhead) n/m (beluga) m (polar bear) M/I (bearded seal)	M/ M (Thick-billed Murre, Black-legged Kittiwake, Dovekie) n (all others)	n (char) M (polar cod)	n/m (hunting) n (fishing)
9 - Cape Harrison - Open Water	n (all groups inshore) m (all groups offshore)	m/I (all species)	m/M (all species, offshore) M/I (all species, inshore)	m/I (all species)	m/M (hunting and fishing)
- Ice-Cover	n (all groups)	m/I (all species) M (harp and hooded seals)	n (all species, inshore) m/M (all species, offshore) M (puffins, offshore)	m/I (all species)	n/m (hunting and fishing)

Like other arctic coasts, there are no permanent littoral and shallow sub-littoral communities. During the open water period, some annual species colonize these zones.

Plankton/Invertebrates

The impact on the plankton of an oil spill or blowout under the ice is expected to be minor. Oil will definitely disrupt the epontic community where it comes in contact with the ice, but because oil movement is considerably restricted in this situation, the effect will be localized. During the period of ice break-up and in open water the oil could be spread much more widely. It would also be subject to weathering. This is an area of good water flow which should disperse the oil and provide for the recovery of the plankton community.

During the spring and summer, when the outflow from the Mackenzie River is at its peak and carries a high sediment load, there is a potential for a localized, moderate impact on the benthos. Oil could be entrained with the suspended sediment and become incorporated into the bottom sediments through deposition. This could result in long term damage to the nearshore benthic community.

Oil could overwash levees during storm surges and penetrate brackish and freshwater lagoons. Vegetation in these areas would be oiled as would bird nesting sites. Waterfowl also use these areas for feeding on grasses and would be subject to external oiling and ingestion of oil.

Fish

The Mackenzie Delta area and the southern Beaufort Sea have the most diverse anadromous and marine fish stocks of any Canadian Arctic area, many of them having potential for commercial fisheries. The marine stocks of cod and flounder are widely distributed and are unlikely to suffer more than a minor impact.

The pelagic shoaling species, herring and capelin, are likely to be moderately affected during the open-water period. These fish spawn on the beaches or in shallow coastal water and their eggs and larvae would come into contact with a coastal spill.

The spawning grounds for the anadromous species are generally in freshwater and the larvae usually remain in freshwater for more than one season, and thus the most sensitive life stages are not threatened. However, inconnu spawn in the ponds and inlets of the delta which are also used by smelts and arctic cisco as larval rearing grounds. These anadromous stocks may be more suseptible to oil impacts from storm surges. Oil on the coast and in river mouths may form a barrier to anadromous fish moving upstream to spawn, perhaps through blocking or confusion of chemosensory abilities. Adults and juveniles of all anadromous stocks range along the coast throughout the year, except for char which overwinter in freshwater, and are likely to be exposed to a coastal oil spill. Adult herring and capelin may also come in contact with oil during the summer when spawning and feeding in inshore waters. In all cases it is difficult to evaluate the impact of a single spill event on the total stocks.

Seabirds

The Mackenzie River Delta and southern Beaufort Sea coast is a major summer habitat for a great variety of shorebirds, waterfowl and seabirds. The southern Beaufort Sea is also the site of a broad frontal migration route for seabirds nesting farther to the east. Because of the importance of this area to such numbers and diverse species of marine-associated birds, an oil spill could have a major impact on some species and probably a moderate impact on most. The Mackenzie Delta is a major nesting area for brant and Lesser Snow Geese. These are specialized shoreline feeders and are likely to be seriously affected by oil which contaminates the coastline. There is also a possibility that their staging areas could be oiled. Species like swans which nest and feed in freshwater habitat are less likely to come into contact with oil. Species feeding offshore or on coastal flats will be more seriously affected. A variety of sea ducks (eiders, Oldsquaws) use the open waters as staging and feeding areas in the spring and fall. These concentrations of

birds, if affected by oil, would have a major impact on the total Beaufort Sea populations.

The impact in the spring during ice break-up is quite variable, depending on when the birds arrive and where the oil is exposed. Birds which are migrating through the area will set down on open water to rest and may be more likely to come into contact with oil when open water is limited. In this case, oil in this area will quite possibly impact populations nesting in other areas. This is probably more the case for sea ducks and geese. The frontal migrations of seabirds occur before there is much open-water so the impact on these populations is likely to be minor.

Moulting King Eider, Oldsquaw, Whistling Swan and Black Guillemot are sensitive to oil because they are divers and will become heavily oiled in feeding. During the moult they are likely to be especially sensitive. During the fall, shorebirds feeding in the intertidal zone could be affected by oil brought ashore with the tide.

Marine Mammals

The impacts on the marine mammal populations are variable and depend on the species. Whales use the area during the open-water season. The bowhead whale migrates through the region in spring and fall and there is evidence that some part of the population may spend time feeding in Mackenzie Bay. The proportion of the total population which might be contaminated by the oil is not known. However, the endangered status of this species would make any adverse effect a moderate impact. Better information on the portion of the bowhead population using this area, their migration routes and summering areas is necessary for adequate impact prediction.

The Mackenzie Delta and adjacent coastal areas provide summer habitat for thousands of beluga whales. Three calving areas are known in this area but feeding areas are not documented. A moderate impact is suggested for this species in light of the coastal calving waters and large aggregations in these areas. This should be qualified by noting that the effect of oil on

whales is not known, nor is it possible to extrapolate oil damage at lower trophic levels to an effect on beluga.

Bearded and ringed seals inhabitat the region throughout the year. Information is scarce on distribution and abundance particularly for the open-water season. In addition, studies on the effects of oil on seals are inconclusive though it is best to assume, under the arduous arctic marine conditions that the ringed and bearded seal would have difficulty if an additional stress, however slight, is placed upon them. Although information is scarce, certain comments may be made. Both species tend to be fairly well dispersed. The ringed seal has a relatively good replacement potential. The bearded seal is less common and replacement potential cannot be properly assessed. However, in both cases the impact should fall within the terms described by a "Moderate Impact". Periods when seals are considered most vulnerable would be during the late winter-early spring when seals are whelping and during spring when ringed seals concentrate along coastal ice to moult. Impacts on a year class of ring seal (i.e., loss of pups for one year) would have a more dramatic effect on polar bears and arctic fox than on the seal population itself. The polar bear has poor replacement potential while the arctic fox has excellent replacement potential.

Since most of the polar bear population moves offshore to the polar pack and effectively leaves the area during the open-water period, it is not expected to be affected by a spill at this time. During the ice-covered season there is a relatively high bear density in this region and the sensitivity of these mammals to oiling would suggest a moderate impact. An oil spill during the winter or oil frozen into the ice from a summer spill and released at a later date could produce similar results.

Arctic fox should also be mentioned since a portion of the population is dependent on the marine environment to feed. However, replacement potential is good.

Hunting and Fishing

This part of the Arctic is undergoing rapid social changes as a result of petroleum development activities. Hunting and fishing are declining in importance for the local people. This makes it difficult to assign an impact value to any level of loss of availability to the resource base. Seals are hunted year round and polar bears are usually taken in winter and spring during the seal hunt. Because a moderate impact to these resources is expected, the same level of disruption has also been assigned to the hunting activity.

There is an abundance of exploitable fish stocks in this region and until recently there were some commercial fisheries. At the present time, fishing activity is limited to sport and domestic fishing activity by the local people. Oil would interfere with fishing through fouling of gear. Oil might also lead to tainting of fish, making it unpalatable. A moderate effect on the fishery can be expected.

MAJOR DATA GAPS

During the open water period storm surges with the potential to inundate and contaminate back beach nesting and feeding areas for birds would seem to be quite important. Identification of the most likely overwash sites and estimation of the frequency of overwashes would allow a more accurate assessment of impacts to the bird population.

A number of gaps in the biological data base have also been discussed above. Of major importance are the use of offshore waters by seabirds, feeding areas for whales and the summer range and migration routes of bowhead whales.

SITE 2: BEAUFORT SEA

SITE DESCRIPTION

This site is located somewhat farther offshore than Site 1 but water depths are still shallow, less than 50 m. The general site description is the same as for Site 1. However, this site, because of it's proximity to the polar pack, may at times be covered by offshore ice.

IMPACTS

The impacts for this site are summarized in Table A.2 and are very similar to those for Site 1 for which detailed explanations have been provided. Impact information given here will only deal with differences between the two sites.

The offshore location of this site will reduce the probability and limit the extent of oiling on the adjacent coastal areas. Weathering of the oil as it travels should reduce the impacts of landed oil. However, oil carried by wind, water and ice will contaminate a potentially much greater area of the Beaufort Sea. The designated spill/blowout location makes it quite likely that under some conditions spilled oil could be incorporated into the polar pack and spread through the Beaufort Gyre. More often it will be carried eastward with coastal currents and may impact the sensitive shorelines and animal populations of Banks Island. There would appear to be more danger of persistent damage from an offshore spill than from one closer to shore.

Plankton/Invertebrates

There is no overall difference in impact between the two sites. With a lower suspended solids load in the water offshore, the effect on the benthos may be less but there may be a greater impact on the epontic and phytoplankton communities as a result of increased dispersion of the oil.

Fish

The marine cod and flounders will not be affected to any greater extent than from a spill at Site 1, but there might be less impact on anadromous species and pelagic shoaling species. This is based on the uncertain assumption that the degree of coastal contamination will be less and that greater weathering of the oil may take place before it comes ashore.

Seabirds

A spill or blowout at this site would affect birds using the offshore waters more than those using brackish and freshwater areas or feeding along the coast. The seabirds which migrate through this area are most likely to be seriously impacted during their westward fall migration. Open-water areas are more extensive at this time than during the spring and the birds are more likely to use this water for resting, feeding and staging. A summer oil spill would have it's greatest impact during the fall migration. However, this assessment is based on incomplete information on use of offshore waters by birds during the late summer and fall.

Marine Mammals

The projected impact on marine mammals is basically the same for this site as for Site 1. Ratings on species do not change, though suceptability of whales may be altered slightly. The fall migration of beluga and bowhead whales is poorly undertood. In general they migrate westward out of the region with a coastal migration for beluga and an offshore or ice edge migration suggested for bowhead. However, bowhead may be seen coastally and not all of the Beaufort Sea beluga's are accounted for by coastal observations.

Hunting and Fishing

The lower probability of extensive oiling of adjacent coastal areas from a spill at this site would perhaps limit the impact on the fishery, especially because of less gear fouling.

It does not appear that there would be any significant difference in the impact on hunting between spills at these two sites.

MAJOR DATA GAPS

The distributions, migration and feeding habits of marine mammals, especially whales, are not well known but are important for reliable impact prediction.

Data is required on densities of marine birds dependent on the region, in particular for sensitive or endangered species.

There is a general lack of knowledge on food chain relations and energy flow in the southern Beaufort Sea - Mackenzie Bay system inhibiting the identification of trophically linked impacts.

A.5.3 Site 3: Armstrong Point

SITE DESCRIPTION

Armstrong Point is located in the middle of the Prince of Wales Strait. This portion of the Strait is narrow (approximately 20 km) over a distance of 70-100 km southwest and northeast of the designated spill site. Maximum mid-channel water depths range from about 165 m at the southern end of the strait to 73 m at the northern end. Ice scour, common to all the spill sites, is the primary factor controlling beach shapes, dynamics and limiting colonization by biota.

IMPACTS

Assigned impacts for all major biological resources are presented in Table A.2.

Plankton/Invertebrates

An impact level on the biological oceanographic system cannot be definitively assigned because of a lack of sufficient information on planktonic and benthic organisms and production processes. This comment applies to both the open-water and ice-covered seasons. The Prince of Wales Strait is probably not a separate biological entity but likely contains populations of planktonic organisms that originate outside of the Strait. Although the 30,000 m^3 spill is projected to cover the Strait during the ice-free months and would affect the phytoplankton in surface waters, the replacement potential of the disturbed populations is good. The magnitude and role of phytoplankton or zooplankton production in energy transfer processes in this area is not known. Arctic benthic invertebrates in general have limited dispersal of larval stages, so that repopulation of any oil-damaged benthic systems will be slower than for populations of more southerly benthic forms.

Fish

During the ice-free season, a moderate impact is forecast for Arctic char summering off stream mouths in the Strait. The wide area covered by the spill and the fact that these types of salmonids frequent the upper layers of the water column would make it very likely that the char would come into contact with oil. This must be qualified with the consideration that no information is available on the size of stocks in this area or on the population structure of the stocks. Also, the effects of oil slicks on adult salmonids are largely undocumented so the predicted impact is somewhat speculative. Effects would most likely arise from alterations in chemosensory faculties of the fish caused by lighter molecular weight hydrocarbons. As the fish probably show fidelity to their natal streams, disruption of populations along the Strait probably would not be readily restored by natural repopulation processes, but would depend upon restocking programs.

Impacts to polar cod are seen as minor at this time because of the cosmopolitan distribution of this species in the Canadian Arctic. Cod eggs and larvae would be particularly sensitive along the length of the Strait; however, no specific data are available on the local timing of spawning and the relative sizes of the fish populations present. Impacts to other species possibly using the Strait would probably be localized and minor.

Negligible impacts to char are foreseen during the ice-covered season while these fish are in freshwater streams and lakes. Once the fish return to the Strait during the summer, the impact could reach the moderate category, dependent upon the weathering and fate of winter-spilled oil in the Strait, an unknown factor. The impact to polar cod is still seen as minor, although data on their winter activities are non-existent. Impacts to other fish species are probably minor.

It is not known that any fish species use the Strait as a migration route but a spill within the Strait could constitute a migrational barrier.

Seabirds

A moderate to major impact is possible for King Eiders and Oldsquaws migrating through the Strait in the spring and fall. Oil could occur in the limited open water spaces that the birds use in the spring. Without accurate knowledge of the percentage of the total populations of these two species using the area, assignment of a specific degree of impact is not possible. The bird sanctuaries on Banks Island are physically removed from the spill site so that direct oiling effects upon birds in the sanctuaries would not occur. Lack of knowledge of the ranges of the birds outside the sanctuaries and of their specific feeding areas leaves open the possibility that the species ranging into the waters of the Prince of Wales Strait may transport ingested or adsorbed oil back to their nesting sites.

Common Eiders, loons, Sandhill Cranes and substantial numbers of shorebirds along the rivers of Banks Island could be vulnerable, but in the absence of more definitive information on specific distributions and numbers of birds, an impact cannot be assigned to these river nesters.

Impacts on birds during the ice-covered season would be negligible, as birds do not occur in the area after freeze up.

Marine Mammals

The present data base indicates that the Prince of Wales Strait is not a critical area for marine mammals. Minor to incomplete impact designations are given to bowhead and beluga whales, ringed and bearded seals and polar bear during the open water season. Polar bear and ringed seal also rate as minor/incomplete during the ice-covered period. With the low level of information available for all species, these projected impacts are presented with reservation.

Hunting and Fishing

Biological resource utilization on Banks Island is very high. Most of the harvesting takes place from populations that concentrate on shorelines outside of the Armstrong Point portion of the Prince of Wales Strait but there is some hunting of polar bears here. For this reason, hunting impacts are foreseen as negligible, based on presently reported resource harvesting patterns.

Impacts on the fish harvesting would be primarily localized and therefore minor. Either as a result of population declines or tainting of flesh and including fouling of gear any fishing effort exploiting the resources along the Strait might suffer detrimental impacts.

MAJOR DATA GAPS

The physical data base is insufficient for simulation modelling of oil slick trajectories. Water current characteristics are only grossly known and weather records at the nearest weather station are not of long enough duration or frequent enough to employ satisfactorily in trajectory models.

The biological data base was not detailed enough to ascertain the degree of utilization of the spill area by bird and mammal populations. This identified deficiency particularly pertains to the birds nesting on Banks Island and migration routes and summering areas for beluga and bowhead whales. Without a comprehensive and comparative data base on fish stocks, especially char, it is not possible to realistically assess the impacts of oil on populations in this area.

A.5.4 Site 4: Viscount Melville Sound

SITE DESCRIPTION

Viscount Melville Sound is characterized by a persistent ice cover. The lightest ice cover that generally occurs is 1-3/10 in September in the eastern portion of the Sound, with heaviest ice buildup in the southern portion. The presence of this ice is the greatest single feature that bears upon an evaluation of spilled oil in the area. Oil spilled in any month but September would be subject to the confining action of landfast ice or very heavy sea ice. Spreading would probably be localized. This statement is made with the reservation that little is known of the horizontal movement of spilled oil under ice. The potential for dispersal of oil by currents under landfast ice is unknown.

Viscount Melville Sound is a large body of water, measuring approximately 270 km east to west by 130-150 km north to south and is shown on the site maps presented in Appendix B. Offshore water depths reach 549 m. The general water mass movement consists of inflows from the west and north (Byam Martin Channel) and outflows to the south (M'Clintock Channel) and east (Barrow Strait).

IMPACTS

The biological information available for this region suggests that it is an area of low biological activity, restricted in part by the lack of open-water. However, data are localized or were the result of casual observations or opportunistic collections. For this reason, the biological data base appears rudimentary.

Plankton/Invertebrates

The biological oceanographic components are given minor/incomplete impact designations for the entire year. A long recovery period is forecast for benthic bivalve populations. The reduced horizontal dispersion of oil

that is likely because of heavy ice conditions will increase the rate of oil transport to the bottom.

Fish

Fish populations of the area are dominated by polar cod and arctic char. Probable impacts from spilled oil would be localized and would affect small percentages of the total populations of these species. Thus these impacts are assessed as minor during the "open" season and negligible to minor during the ice-covered season. Victoria Island stocks are the most likely to have contact with oil because of the current and wind directions. However, the sea ice would tend to keep oil away from river mouths where char are likely feeding.

Seabirds

Seabird and waterfowl use of the area is limited. Identified bird concentration areas all appear to be upwind and upcurrent of the hypothetical spill site so that the probability of contact with the oil by birds while feeding would be low. Minor impacts are therefore foreseen for a spill occurring during September, and negligible impacts for spills during the rest of the year. As in other cases, the spill during ice-covered periods would likely have a greater impact once ice begins to break up, the oil disperses, and biological activity increases.

Marine Mammals

Most marine mammal activity in the area is concentrated, as for the birds, upcurrent from the designated spill site. Minor impacts to seals and minor to moderate impacts to polar bears are projected during the period of limited ice break-up. The polar bears concentrate on the permanent ice off northeast Victoria Island where they could contact oil blown southward with moving ice cover during August-October. Minor impacts to these species are forecast during the rest of the year because of the probable localization of oil in

the fast ice. Those seals using natural leads or those opened by ships would have a higher probability of being oiled from a spill. However, they probably represent a small proportion of the total populations and thus any impact would be small.

Hunting and Fishing

With no communities in the spill area, and no known resource harvesting of any degree, impacts to resource users would be negligible.

General

In addition to the above characteristics and probable impacts of spilled oil in Viscount Melville Sound, several further points of a general nature deserve mention. Because of the persistence of ice cover in this area, oil dispersion will be limited. However ice and water in this area moves generally to the east and south. During transport through the spring and summer months, ice progressively disperses and thus horizontal dispersion of any spilled oil would also accompany ice movement. The net effect of spilled oil in Viscount Melville Sound thus would be an export of oil and its subsequent effects to the Barrow Strait and Lancaster Sound and to the M'Clintock Channel. Accompanying the dispersal of the oil will be natural weathering which should lower its toxicity to marine life.

MAJOR DATA GAPS

A sparse biological data base for the area is a data deficiency common with many other Arctic areas. Accurate knowledge of the long-term oil weathering characteristics in and under ice prevents accurate prediction of spill impacts for areas outside of the immediate spill area.

A.5.5 Site 5: Sverdrup Basin

SITE DESCRIPTION

This site is located in the MacLean Strait south of Ellef Ringnes Island and north of Bathurst Island at 77°20'N, 102°30'W. Water depth in this region ranges from 100-500 m. It is an area of low coastal relief with abundant sand and gravel deposits along the coast. The tidal amplitude is less than 1 m and the lack of a distinct open water period limits wave action. Consequently these are low energy coasts with limited reworking of sediments. The action of moving ice dominates coastal processes. The minimum average ice cover is reached by September when only 4-6/10 is covered with ice. The currents here are thought to be weak and this would imply that export of oil from this site would be a very slow process with continuing contamination over several years. The low temperature and continuous ice cover would also limit weathering and so retain the more toxic aromatic fractions for a longer period.

IMPACTS

The data base for assessing impacts of an oil spill or blowout at this site is poor even by comparative standards for other Arctic regions. There are virtually no data on currents at any time of year and the heavy year-round ice cover makes it impossible to predict the behavior of oil in this environment, since assumptions associated with open water behavior of oil are inappropriate. The high level of uncertainty regarding the fate of any oil spilled and the lack of any information on the biological systems are reflected in the assessed impacts (Table A.2).

Plankton/Invertebrates

There is insufficient information to assign any impact to the plankton and benthic communities. No studies have been done in this region and thus, the nature of these communities and their importance in ecosystem functioning are unknown. The lack of an open-water period implies that production might be

dominated by the epontic flora but nothing is known of its timing, biomass, productivity or utilization.

Fish

Runs of char have been identified in rivers of Ellef Ringnes and Bathurst Islands which drain into the MacLean Strait but no systematic surveys have been done to assess these stocks. Polar cod are ubiquitous through the Arctic Islands and are expected in this region but no stock assessments have been done. On the basis of the available biological information and environmental conditions, the fishery resources are considered to receive only minor impact. This is qualified by the fact that the data base on which this judgement was based is not adequate to assign impacts with any certainty.

Seabirds

Utilization of this site by birds is limited. There is a brant colony on the east side of Ellef Ringnes and a small Glaucous Gull colony on northern Devon Island. Without knowledge of the area likely to be affected by oil, no assessment can be made for these colonies.

A very important Ivory Gull colony is located on Seymour Island. This species is uncommon in the Canadian Arctic with only two known nesting sites. Consequently damage to a single colony could have serious effects on the whole population and thus a major impact is designated for this species.

Marine Mammals

The data base for assessment of impacts is very limited. Polar bear, bearded seal, and walrus are found year round in the Penny Strait area. This is the main channel for water leaving the area and oil would most likely pass through, resulting in a high probability of contaminating resident animals. A moderate impact has been tentatively assigned to these species in light of the likelihood of contact with oil. Although ringed and bearded seals are present, there is no information on their distribution or abundance and thus

no impact level designation has been made for these species, though replacement potential for the former should be considered good.

Hunting and Fishing

The resource utilization impact is considered to be negligible. This area is not used as a hunting territory for Inuit so any adverse effects on the biological resource by an oil spill would not have any direct impact. It is possible that there would be an indirect impact through a reduction in population density of prey species over a much broader area.

MAJOR DATA GAPS

Without a comprehensive data base on the physical oceanography, on the behavior and fate of oil in ice-rich environments, and on the plankton and invertebrates of this area, it is not possible to evaluate biological impacts with any degree of accuracy.

A.5.6 Site 6: Allison Inlet

SITE DESCRIPTION

Allison Inlet is located on the south coast of Bathurst Island. Water depths throughout this area range from 100 to 200 m with depth increasing towards Viscount Melville Sound. A number of islands are present in Barrow Strait. The shallow water in Barrow Strait creates a sill which limits the westward penetration of warmer deep waters formed in Lancaster Sound, resulting in Arctic surface water dominating the area. Low energy shorelines and coastal features dominate the region, the result of a very limited open-water period restricting fetch and wave action. Coastal environments are dominated by the effects of ice scour and the formation of landfast ice.

This area comprises a mixture of coastal types, ranging from steep talus cliffs and fjords to sand and cobble beaches on lowland coasts. Mud flats develop in sheltered areas. Generally, limited wave activity (low energy), prevents extensive sediment redistribution.

Water enters this area from the north and west and undergoes some mixing before exiting to the east and south. There is a general narrowing of the channels to the east with islands and restricted passages creating more turbulent flows and perhaps a gyre circulation north of Peel Sound.

There are some small polynyas in the inter-island channels north of MacDougall Sound but the biological significance or importance of these is unknown.

In general this area is characterized by highly variable ice break-up and "open-water" ice conditions on a yearly basis. Ice never entirely clears especially in Viscount Melville Sound. A stable landfast ice edge forms across Barrow Strait in the winter of most years and persists until late summer, but its location can be quite variable. This feature is very important biologically but its variable yearly positioning makes it impossible to give it a precise geographical location.

IMPACTS

Table A.2 summarizes the impacts on all major biological resources for this site. Impacts on the shores and beaches are expected to be minimal as a consequence of limited biological development in these environments. There are no permanent biological communities established in the littoral or sublittoral to a depth of about 5 m although some annual species are found in these environments during the brief ice-free period. Oil on the shores poses a more serious threat to birds and mammals using these areas. Given the location of this spill site, shoreline contamination by a large proportion of the oil becomes a major consideration. Simple calculations of slick area indicate that very long stretches of coast could become extensively oiled, especially during open-water conditions and southerly winds. Under more common prevailing northerly winds the oil may be carried offshore into Barrow Strait. Under this condition, the 30,000 m^3 spill is the only case likely to impact other coastal areas in a significant way. The smaller spill sizes can be expected to have more local impacts and to be less persistent.

Migration of oil slicks under ice is considered to be much more limited than that observed on open waters. For this reason oil spills of any size are expected to remain highly localized during the ice covered season. This is countered by the greater persistence and absence of weathering of oil trapped in ice. The limited open-water period in this area (< 60 days) may result in oil persisting in the water for several years in a cycle of exposure, incorporation into new ice and repeated exposure.

Plankton/Invertebrates

The data base for this area is extremely limited; it consists of a single study in Austin Channel, one in Barrow Strait and a cluster of local studies in the Resolute Allen Bay area. There is a moderate level of productivity by Arctic standards and where substrate allows in bays and inlets, benthic productivity through algal macrophytes becomes an important component. The role of macrophytes in energy flow in these systems is not well known.

The lack of sufficient information to form general conclusions about the productivity, biomass and energy flow in the benthic and plankton communities makes any impact evaluation incomplete and conditional. However, based on available information, the impact on the benthos and plankton is considered to be minor under open water conditions. A spill may reduce epontic and plankton productivity for one or more years but there appear to be good chances for replenishment and recovery. Effect on the benthos is less well defined as this community will be much slower to recover due to limited recruitment from outside sources, slow growth, late maturity, low reproductive capacity and extreme persistence of oil in bottom sediments in this low energy environment. Areas between 5-75 m are the most sensitive and impact will depend on the areal extent and degree of contamination. The effect of reduced primary productivity and benthic production for an unknown length of time on higher trophic levels is much harder to assess. The geographic extent and location of this damage will be of special significance.

Fish

There has been no systematic fishery survey to determine the distribution and stock abundance for any species. The lack of any data beyond casual observation and identification of locations of subsistence fisheries makes it impossible to realistically evaluate the impacts of oil on the fishery resources. Polar cod are generally distributed through the Arctic and are considered to be a major food source for birds, mammals and other fishes. It is not known, however, whether discrete stocks exist in particular areas or if the species mixes freely throughout its range. There is a potential for serious damage to polar cod since the more sensitive eggs and larvae are pelagic and are found close to the surface under ice. The adults also inhabit surface water under ice and along ice edges although they are found in deeper waters as well.

Arctic char exist as highly localized stocks associated with their natal rivers. They are most sensitive during the open-water season when they are feeding in coastal waters off river mouths or during their passage up and down the rivers. Thus, the effects on char are likely to be highly localized and dependent on where the oil strikes coastal areas and river mouths. All

rivers with overwintering habitat are likely to have runs of char. The extended freshwater juvenile stage for char may give a stock some protection from a single spill event but this is dependent on the age structure of the population and the persistence and effect of the oil.

Seabirds

This area does not have major nesting areas for any bird species although small colonies are dispersed throughout the region. Many of the colonies are north of Barrow Strait on the islands of Queen's Channel and MacDougall Sound. The most sensitive area for birds is the ice edge across Barrow Strait, especially in spring when migrating birds rest and feed en route to their nesting areas. During the summer, this ice edge and others throughout the region are important feeding locations for birds from a wide area. As a result, oil contamination here could potentially impact bird colonies over a much wider area.

Consideration of these factors indicates that a moderate impact can be expected for birds throughout the region. The varible location of the ice edge on a yearly basis prevents identifying the most biologically important sites.

Marine Mammals

The impact of an oil spill is uncertain for marine mammals. The direct effects of oiling are not well known for seals and whales and these animals may be able to avoid prolonged or serious exposure. Polar bears appear to be more sensitive to oiling but there is very limited specific information on their ability to avoid oil. All mammals may be indirectly impacted through the loss of favored habitat or loss of major food supplies.

The impacts on whales (beluga, narwhal) is considered to be negligible during the ice-covered period and minor during open water. Abundance of summering whales is not large in this region, lowering the potential impact of oil on the entire population. This impact designation could be modified if it were shown that separate sub-populations occupied specific summering areas. The

most sensitive period is expected to be spring when these animals are moving westward in restricted leads where there is less opportunity for avoidance of oil.

Bearded seals are expected to sustain only a minor impact due to their scattered distribution year-round and their selection of wintering sites. Although the latter are not well known they are thought to favour polynyas and leads in pack ice especially in shallow coastal waters.

The walrus population in this area is small but due to their habit of congregating in favoured areas they could be moderately impacted. There are some walrus overwintering in polynyas in the northern part of this map area so they can be expected to be vulnerable year round.

Barrow Strait is considered to be a major wintering area for ringed seals due to their preference for first year landfast ice. This results in a considerable overlap between distribution of birth lairs and preferred tanker routes. Ringed seals are more dispersed in the summer but oil will also be much more mobile at the time than under ice and thus a potentially larger portion of the resident population may be affected. The local effect of spilled oil in the winter results in a minor impact rating while the open water season has been assigned a moderate impact for ringed seals. It should be noted that in both cases, this rating is based on incomplete information on the distribution and density of ringed seals in this area and the lack of good understanding of the effect of oil on these animals. Also, where seal populations are large, there is an improved possibility of recovery.

Polar bears are wide-ranging in the winter and are more likely than other marine mammals to come in contact with oil spills. They also appear to be quite sensitive to oiling and impact is considered to be moderate. In summer, bears retreat to the coast and are less likely to come in contact with oil but do return to the ice very early in the fall.

Hunting and Fishing

This is an important hunting and fishing area for the native residents of Resolute. The effect on hunting has been tentatively assigned a moderate to major impact in the absence of specific information on the effect of oil on the hunted species. However the potential impact is considerable. Oil-induced mortality may reduce prey availability; oil avoidance may change distribution of prey and reduce availability; contamination by oil may decrease the value of pelts and hides; and the flesh may become tainted and unpalatable.

As discussed above, the effect on char fisheries is expected to be localized. However, at these locations the impact is potentially moderate due to gear fouling and the direct effect on the stocks. In the winter the effect on fisheries would be negligible.

MAJOR DATA GAPS

There are major weaknesses in the available biological information but the more fundamental lack of information relates to the physical environment in this area.

There is a limited amount of information on currents. What is known indicates that the currents may be highly variable in time and space. Evidence of a gyre north of Peel Sound raises the possibility of increased persistence and the opportunity for any spill to be very widely spread. This is also an area of prolonged ice cover and the effect of this on oil persistence and movement is unknown.

Biologically, the importance of the offshore benthos to energy flow in this system is not known and consequently the impact of damage to this community cannot be assessed.

A.5.7 Site 7: Cape Liddon

SITE DESCRIPTION

Cape Liddon is on the southwestern tip of Devon Island facing on Barrow Strait, at the juncture between the eastern end of Barrow Strait, Wellington Channel to the north, Lancaster Sound to the east and Prince Regent Inlet to the southeast. Water depths within the Strait reach maxima of 165-238 m. Wellington Channel is approximately 40 km wide at its juncture with Barrow Strait, which is about 68 km wide at Cape Liddon. An important environmental characteristic of this area is that the timing of freeze-up and break-up is variable from year to year. The eastern limit of landfast ice is generally in the western end of Lancaster Sound and recedes to the region of Cornwallis Island in the Barrow Strait in the spring. The retreating ice edge functions as a travelling focal point for biological activity: epontic production; seabird feeding; polar cod feeding; marine mammal feeding and staging; and polar bear feeding. The timing of the retreat of this front is highly variable and represents a limiting factor in the ability to predict area specific impacts for given times of the year.

IMPACTS

Plankton/Invertebrates

As the Cape Liddon area of the Barrow Strait appears to be flushed with water from several sources, representing reservoirs for the replenishment of biological resources within the area, minor impacts from spilled oil to plankton and invertebrates are predicted within the ice-free season. Localized areas along the ice edges and in protected inlets will likely sustain moderate impacts. The available phytyoplankton, zooplankton and benthic information probably is more reflective of the distribution of sampling effort than actual biological distributions so that site specific impacts or impact predictions for ecosystem interactions are necessarily imprecise. As noted in the site description, the ice-front probably represents one of the most important sources of biological activity, so that a spill occurring during ice break-up would do the most damage at this front.

During the ice-covered season, impacts would likely be minor. However, as ice break-up proceeded in the spring, winter-spilled and concentrated oil would then begin to affect a wider area and the level of impacts would approach those detailed above for the ice-free season.

Fish

Data on the fishery resources for the spill area are insufficient to predict the probable impact of an oil spill on this environmental component for any portion of the year. Arctic char and polar cod are reported for the area, but information on stock sizes, discreteness of populations and seasonal movements and concentrations are lacking. Char have been reported in coastal waters of southern and eastern Cornwallis Island and northern Somerset Island during the ice-free season, and polar cod are known to concentrate along the ice front. The relative importance of different streams for char is unknown. As Arctic char are known to inhabit freshwaters during the winter, they would be unaffected by a marine oil spill during that period. However, once they returned to the sea in the spring, they would be susceptible to contact with oil.

Seabirds

Seabird utilization of the Cape Liddon portion of Barrow Strait is high. A major impact on murres and Northern Fulmars would probably result from spilled oil during the ice-free season. This degree of effect is assigned because of the large numbers of these two species nesting, migrating, and feeding in the area. Known colonies in the area support a significant proportion of the world's breeding populations. Impacts to all other bird species in the area would likely be moderate because entire populations would not likely be affected. The retreating ice edge is highlighted as an important seabird concentrating area. A spill occurring in the ice-covered season would have a negligible impact on seabirds because the birds are not present. However, with the early arrival of some bird species (eiders) to feed in polynyas in early spring, impacts would be moderate to major.

Marine Mammals

Marine mammal sensitivity to spilled oil in the Cape Liddon area during the ice-free season would vary greatly depending upon the location of the ice edge with respect to the location of the spill. A spill after the front had passed to the west of Cape Liddon would probably have a small effect on the ice-edge concentrations because predominant winds and currents would likely drive spilled oil to the east and southeast of Cape Liddon. Moderate impacts on walrus, narwhals, ringed seals, and polar bears are predicted because of the relative abundances of these animals with respect to total population sizes or because of their apparent high sensitivity to oil (polar bears: Englehardt, 1981). Beluga and bowhead whales could sustain moderate to major mortalities, dependent upon their sensitivities to oiling, an unknown factor. June to early July concentrations of beluga whales at ice edges of Barrow Strait and Prince Regent Inlet may represent a large percentage of the total beluga population using the central Canadian Arctic. Bowhead are very limited in numbers in the eastern Canadian Arctic and are potentially vulnerable due to poor replcement potential. Bearded seals would receive a minor impact from a spill because effects would be upon a small proportion of the widely distributed population.

Hunting and Fishing

Polar bears and seals are harvested by natives within portions of the study area, particularly along southern and eastern Cornwallis Island and southwestern Devon Island. These areas are relatively far from the nearest settlement, Resolute Bay. Damage to exploitable resources would be primarily to the east and southeast of Cape Liddon where resources do not appear to be presently harvested. In the event of damage to exploited stocks through oiling mortalities or reductions in meat or hide desirability, alternate hunting areas may be used more heavily so that a major loss of the total resource to the community appears unlikely. Potential impacts to hunting throughout the year are seen as minor to moderate. Information on exploitation of the fishery resources is not detailed, although localized oiling damage to char or polar cod could probably be compensated for by switching to alternate harvesting locations. Oil trajectories based only upon wind and

surface current directions suggest that spilled oil would disperse away from present resource harvesting areas in the western and northern portions of the area. For these reasons, negligible to minor impacts upon fishing are foreseen.

MAJOR DATA GAPS

In addition to uncertainty over the fate of spilled oil in the hypothetical spill area, two factors stand out as data gaps. Annual variability in the retreat and formation of the ice edge through Barrow Strait limits time and area specific designation of probable impacts. There appears to be a poor capability for predicting the timing of this event. Knowledge of the fish populations is still at a descriptive stage and deficient concerning stock sizes, discreteness of populations and seasonal movements and concentrations.

A.5.8 Site 8: Cape Hay

SITE DESCRIPTION

Lancaster Sound represents one of the most intensively-studied areas of the Canadian Arctic. The Sound is approximately 90 km wide at its eastern end and 70 km wide at its western terminus where it meets Barrow Strait. Length of the Sound is about 260 km. Water depths range from approximately 200 m in the Barrow Strait to greater than 700 m where the sound opens into Baffin Bay. A number of bays on the coast of Devon Island indent the northern perimeter of the Sound while the south is divided by three large inlets: Prince Rupert, Admirality, and Navy Board Inlets. All of these inlets and bays serve as important areas for marine life, particularly the varied species of marine mammals that inhabit the area.

IMPACTS

The major predicted feature of a 30,000 m^3 oil spill within Lancaster Sound is that it would be large relative to the dimensions of the Sound. Because of the prevailing current regimes, spilled oil in the northern portion of the Sound during the ice-free season might first travel westward, then be entrained with eastward-flowing currents in the southern portion of the Sound. Significant coastal contact of both Devon and Bylot Islands could occur under these conditions. Eventually, oil would probably travel out into Baffin Bay.

Plankton/Invertebrates

The overriding biological feature of Lancaster Sound is its biological productivity and high degree of utilization by marine mammals and seabirds. Ice break-up earlier than other parts of the Arctic probably makes the area attractive to these species. Shifting ice with a persistent lead in the ice along south coast of Devon Island during the ice-covered months also provides critical open-water habitat to over-wintering species.

For the ice-free season, a moderate impact of a 30,000 m^3 tanker spill on the biological oceanographic components is predicted (Table A.2). A spill in the early parts of the open-water season when the epontic bloom is taking place and during July to September at the time of the phytoplankton bloom could inhibit carbon fixation over fairly large areas of the sound for an unknown length of time. With the present data base, it is not known whether the producers are all indigenous to Lancaster Sound or whether Baffin Bay and Barrow Strait represent reservoirs for primary and secondary producers. If the Sound functions as an independent system, then impacts on these trophic levels could persist throughout the relatively short season for plant growth. With constant replenishment of stocks from outside sources, effects on higher trophic levels as a result of damage to the producers may be lessened and of short duration (less than one season). If a substantial proportion of one year's primary production within the Sound was retarded by an oil spill, the resultant effects on higher trophic levels could persist for many years.

The loss of algal production for one season would severely limit the zooplankton production and the potential for replacement of a new cohort the following year. Loss of this resource would be felt through the food chain from polar cod (larval and juvenile feeding requirements), to seabirds and to baleen whales. Damage to benthic populations would be likely, but it is not known at which concentrations lethal or sublethal effects would predominate. Likelihood of damage to deeper water benthic organisms and the role that they play in the marine food chain of the area are not known.

Recovery of benthic communities from oil damage would be very long-term, at least on the order of one to two decades based upon growth data for arctic bivalve molluscs.

A spill during the ice-covered season would likely remain localized and concentrated under ice and in shifting leads. There is uncertainty over the probable degree of horizontal dispersion of oil under ice. A minor impact is predicted during this time of year with the designation shifting to a moderate impact level when ice break-up occurs and biological production processes increase in intensity.

Fish

The impact level to the fishery resources of Lancaster Sound is assessed as moderate for polar cod and negligible to minor for other species during the ice-free season. Polar cod retain the same rank for the ice-covered portion of the year. Polar cod would be most susceptible to oil damage in the egg and larval stages. Although previous studies have noted the presence and distribution of polar cod in the area, no data appear to be available on the relative discreteness of stocks in different geographical areas such as Lancaster Sound. Without being able to assess the replenishment capability and potential of Lancaster Sound stocks, the assignment of impact level is tentative and in need of further refinement. Damage to cod stocks would represent a decrease of a major food resource of many birds and piscivorous marine mammals. In the absence of alternative food sources that could be preyed upon, viability of these predators would most certainly be reduced.

Impact on Arctic char would be negligible because the species over-winters in freshwater streams or lakes. Arctic char use coastal waters around river mouths during the ice-free season, and use the deeper waters of Lancaster Sound to a lesser extent. However, reported char distributions often reflect their proximity to native settlements and to ease of access for fishing. Adult char are the only stage that might be directly impacted by spilled oil.

Seabirds

Seabirds would suffer the greatest direct and indirect (oil effects expressed through the food chain) effects of all of the biological resources of Lancaster Sound. A major impact is predicted for Thick-billed Murres, Northern Fulmars, Black-legged Kittiwakes and Dovekies. A moderate level of impact would prevail for all other species. A major impact designation is based upon the large proportion of the total populations of these birds using the Lancaster Sound area for breeding nesting, and feeding. The fact that they all spend time on or dive into the water (particularly in the case of Murres and Dovekies) increases the probability of oiling. The potential for spilled oil to travel over a large portion of the Sound increases the

likelihood of impact upon localized bird concentrations. In addition to direct oiling effects, loss of food sources could have severe impacts upon the fitness of existing adults and survival and recruitment of young for a number of years. The low fecundity and long lifespans of many of these seabirds would mean that rejuvenation of damaged stocks would be a long process, if it occurred at all.

During the ice-covered season, the birds would be further south or in Greenland waters in their overwintering habitat. Impacts would therefore be negligible until the spring break-up when spilled oil that had remained somewhat concentrated during the winter began to spread out and birds returned to the area for the ice-free season. The impacts of a winter spill would then be manifested as moderate to major impacts dependent on the residual toxicity of weathered oil, the rate of physical dispersion of the surface oil, and the rate of transport of oil out of the Sound and into the open waters of Baffin Bay. The long-term fate of spilled oil in cold, polar waters is poorly understood so that impacts beyond immediate oiling are largely conjectural.

Marine Mammals

Impacts to marine mammals from spills during the ice-free season vary from negligible to major. Bowhead whales could receive moderate to major impacts from an oil spill, primarily because their population numbers in the eastern Canadian Arctic are extremely low . Their feeding habits also link their sensitivity to that of the planktonic community. In the absence of direct oiling effects, major reductions in the food sources of bowhead could reduce the fitness of the population, and hence its capability to adapt or compensate for the natural environmental pressures acting upon it. The absence of information on summer feeding areas and congregation patterns reduces the certainty with which accurate predictions of the level of environmental impact can be assigned for this species.

The beluga whale population would be moderately impacted. Seals would be impacted to a minor degree; however, because of a lack of knowledge of their

numbers and discreteness of populations, an incomplete data base designation must qualify the level of impact assigned.

A minor impact would result with walrus, primarily because only localized parts of the eastern Canadian Arctic population would be affected by a spill though again an understanding of stock discreteness is required. Contact with oil is possible at any time during the summer (July-October).

Minor effects would result with polar bear. The level of sensitivity of this species to oil appears to be high, but it is widely dispersed throughout the Canadian Arctic. The net result is that a small proportion of the population would be affected by a major spill in Lancaster Sound. Differential susceptibility to oiling would prevail with highest susceptibility during spring and fall when the polar bears concentrate along ice edges to feed. During summer when they retreat to land, their contact with the water would be somewhat reduced.

Narwhal sensivity to oil is unknown. The large proportion of the population that migrates through Lancaster Sound from mid-June to late July suggests that a moderate impact level be assigned. Damage to the benthic food sources of narwhal and walrus could be long-term. The ability or inclination of populations to shift their feeding areas to accommodate for destruction of traditional feeding grounds is unknown. Narwhal concentrate in large numbers during the fall migration along the southern coast of Devon Island, making them sensitive at this time.

During the ice-covered portion of the year, marine mammal use of the area drops substantially. Bearded seals, ringed seals and polar bears are the main species resident during this period. Impacts on polar bears would be minor. Bearded seals may be impacted to a moderate level because they tend to use open leads but the possibility exists that this species leaves the area during winter. Uncertainty over this point is the reason for an incomplete data base assignment with the impact level (Table A.2). Because of the uncertainty of the extent of oil dispersion under ice, it is difficult to assign ranking to the other seal species for the ice-covered period.

Hunting and Fishing

Resource utilization would be moderately impacted by a spill during the ice-free season. Declines in the populations that are being harvested would mean few animals for harvest while tainting of tissues and hides with oil would reduce the desirability and marketability of the resources. If such an event did occur, a shift in the food-gathering habits of the native people would be required for subsistance in the absence of government and industry aid to supplement the lost resource. During the period of recovery an important component of the lives of the Inuit, the traditional provision of basic foodstuffs through subsistance hunting and fishing, would be removed. A spill during the ice-covered period would result in minor to negligible impacts to resource use because of the probable localized impact of spilled oil in ice on the resources. Most of the fishery activity for ringed seals, which are probably the most important mammal harvested, takes place outside of Lancaster Sound and thus negligible impacts are forseen for utilization of this resource.

MAJOR DATA GAPS

The most serious data gap is knowledge of the long-term fate of oil. Little is known of the discreteness of populations. There would appear to be a potential for oiling damage to deep water benthic communities, although this point cannot be substantiated. As well, the role of these communities in energy transfer is not clear. Narwhal are likely to be oiled, yet little is known of their oiling sensitivity.

A.5.9 Site 9: Cape Harrison

SITE DESCRIPTION

This is the most southerly of the study locations, located east of Hopedale at 55°29'N, 57°30'W in about 200 m of water. It is on the shelf edge and water depth to the east drops off rapidly to 2000 m. The exposed Labrador coast is a rocky, high wave energy environment when ice-free, with a tidal amplitude of more than 3 m. Landfast and offshore pack ice cover this area from December to July.

The coast is a rocky, high relief, fjord-type with small cobble/pebble beaches in sheltered areas.

Water movement is dominated by the Labrador current which flows south along the coast.

IMPACTS

As a result of the prevailing wind and current direction an oil spill at this site is most likely to remain off the Labrador coast and be carried from the study area by the Labrador Current. This is especially true when the area is ice-covered as the ice will act as a barrier to the shoreward movement of oil. During the ice-free season oil which comes ashore will have undergone some weathering and will be less toxic. Wave action and ice scour on the exposed coastline would make any grounded oil less persistent. Localized sheltered areas where beaches and some littoral communities have formed and where oil contamination is likely to be more persistent will be the most sensitive coastal areas. Because of the location of this site and the distribution of the biological resources, the impacts have in some cases been subdivided into onshore and offshore impacts (Table A.2).

Plankton/Invertebrates

A large oil spill or blowout would have considerable direct impact on plankton productivity but the open nature of this system and the opportunity

for dispersion and dilution offered through the action of the Labrador Current moderate the final impact.

During the winter, oil could be expected to cause extensive disruption to the epontic community but the importance of epontic production to the total productivity of this area is considered to be minor. The presence of landfast and pack ice would prevent wind action from moving any oil to shore, eliminating any damage to the shallow water benthos. A blowout would probably disrupt the offshore benthic community for some distance downstream, but it is basically a local effect. For these reasons, the impact of a blowout or oil spill on the plankton and benthos during the ice season is considered to be negligible.

During the open-water period the effect of oil on these communities is slightly greater but is still minor. The timing of a spill is a critical factor in determining the impact. The copepod species which dominates the zooplankton in this region has a single reproductive pulse which coincides with the spring phytoplankton bloom. Since this copepod population is heavily preyed upon by higher trophic levels, including fish, the potential impact may be moderate. The localized nature of such an effect and the good replenishment potential would seem to limit the impact at this secondary producer level to a single season. The distance from shore of this spill site suggests that any oil reaching shore would be somewhat weathered and would have lost some of its acute toxicity characteristics. However, the physical smothering action of this oil may seriously affect the littoral communities in sheltered bays and inlets, where wave action cannot help to clean up the oil. The populations and communities on these coasts are not unique and have good replacement potential indicating a negligible impact. These environments may be slower than more temperate ones to recover, but it is still expected that they will do so. Although oil will not persist along this exposed coast, an open water spill which was blown ashore could be held there over winter by ice formation thus increasing the impact to nearshore environments.

Fish

In general the effect on fish stocks is considered to be minor but this must be qualified. This evaluation is based on a consideration of the likely effects of a single spill. Long term exposure of this environment to oil could result in severe damage to fish stocks. The important Hamilton Banks are immediately south of the spill area and are likely to be affected as a result of current transport of spilled oil. A single spill is not considered to affect a significant portion of any stock but repeated exposure could influence recruitment. Eggs and larvae are the most sensitive stages, with different species being most affected during their spawning season, usually the open-water period.

The anadromous stocks of char and Atlantic salmon are sensitive to marine oil spills only during their movement in and out of rivers. Because of the location of the spill site, there is a low probability for any single stock to be affected and the lessened toxicity of weathered oil should reduce this impact.

Seabirds

The Labrador coast is a major migration route for a large number of waterfowl and seabirds but it also has significant local seabird populations year round. Seabirds overwintering on the Labrador Sea would be impacted by oil escaping along the ice edge. The most serious impact along the ice edge would be to murres which congregate there in the spring.

There are no overwintering seabirds along the coast but during the open-water period this is a suitable environment for nesting and feeding for a variety of seabirds. Special consideration must be given to the Atlantic Puffin colonies on the coastal islands as they make up an important part of the total puffin population. These birds are susceptible to oiling damage because of their poor flight capabilities. Oil may have a moderate effect on these colonies but this must be qualified in terms of the prevailing currents and winds which reduce the probability of contact. There is also the question of whether contact with weathered oil is less serious than with

fresh oil. Black-legged Kittiwakes and Northern Fulmars are found in the offshore areas during the open water period and their populations could also be moderately affected by an oil spill.

The greatest danger to birds from an oil spill in this area would likely be during the fall migration period when the area is used by large numbers of ducks and geese for staging and feeding.

Marine Mammals

The Labrador coast is an important migration route and summer feeding area for seals and whales. The effects of oil on these mammals is not well known, making it difficult to assign an impact. Major concentrations of whelping seals occur on the ice over the Hamilton Banks to the south of this site in March and April, and a northward migration along the ice edge and coast occurs from April until late May. There is some danger that these animals, especially the pups, could come into contact with an oil spill drifting south under the ice. Also, major feeding concentrations of whales and dolpins occur in this same area during the late summer. Replacement potential for the seals is good, however significant numbers may be affected. A major impact is projected based on the larger spill size. Smaller spills would drop the rating to minor. Additional information is required on the effects of oil on marine mammals to more accurately designate the ratings.

Hunting and Fishing

There is a high level of utilization of the fishery resources of the area. The difficulty lies in predicting the impact of an oil spill on this utilization. Oil may directly affect this activity through increased mortality and lowered catches or through tainting of fish flesh making the catch unmarketable. Indirectly, oil may foul fishing gear making fishing difficult if not impossible. The impact assigned depends on the geographical extent of the effect and the amount of disruption caused to fishing effort. No more than a moderate impact during the open-water period is foreseen. The much-reduced fishing effort during the ice-covered period would reduce the impact to minor.

The dispersion of oil by the Labrador Current southwards could also result in some disruption of the offshore fishery on Hamilton Bank through fouling of gear, some increased mortalities of fish and flesh tainting.

APPENDIX B

ENVIRONMENTAL DATA SUMMARIES

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KEYS TO THE USE OF MAP SYMBOLS

1. Plankton/Invertebrates:

Pl - Polynyas and Leads
Pp - Primary Production
Zb - Zoobenthos
Zp - Zooplankton
◯ - Spill Site

2. Seabirds

Example: NMo: WfGG --- Nesting and Moulting for Waterfowl and Glaucous Gulls

HABITAT USE

F - Feeding
G - Range
M - Migration
Mf - Fall Migration
Ms - Spring Migration
Mo - Moulting
N - Nesting
S - Staging
W - Wintering

◯ - Spill Site

SPECIES

AB - Atlantic Brant
AP - Atlantic Puffin
AT - Arctic Tern
BB - Black Brant
BG - Black Guillemot
Br - Brant
CM - Common Murre
CE - Common Eider
DV - Dovekie
Ed - Eider
Fu - Fulmar
GB - Great Black-backed Gull
GG - Glaucous Gull
Gu - Gull
HG - Herring Gull
IG - Iceland Gull
IU - Ivory Gull
KE - King Eider
KW - Black-legged Kittiwake
Ln - Loon
LP - Leach's Petrel
Mu - Murres
NF - Northern Fulmar
OS - Oldsquaw
Ph - Phalarope
RP - Red Phalarope
RZ - Razorbill Auk
Sb - Seabirds
Sh - Shorebirds
SG - Sabines Gull
SN - Snow Goose
TG - Thayer's Gull
TM - Thick-billed Murre
Wf - Waterfowl
WG - White-fronted Goose
WS - Whistling Swan

KEYS TO THE USE OF MAP SYMBOLS (CONT'D.)

3. Marine Mammals

example: R: BS --- Pupping Area for Bearded Seals

HABITAT USE		SPECIES	
F	Feeding	AF	Arctic Fox
G	Range	BH	Bowhead Whale
M	Migration	BS	Bearded Seal
Mf	Fall Migration	BW	Beluga Whale
Ms	Spring Migration	GS	Grey Seal
Mo	Moulting	HD	Hooded Seal
R	Reproductive	HR	Harbour Seal
S	Staging	HS	Harp Seal
		NW	Narwhal
		PB	Polar Bear
○	Spill Site	PW	Pilot Whale
		RS	Ringed Seal
		W	Whales
		WL	Walrus

4. Fishery Resources

AC	Arctic Cisco
AP	Atlantic Plaice
AH	Atlantic Halibut
CH	Char
CA	Capelin
CO	Cod
Fl	Flounder
GR	Grenadier
GC	Greenland Cod
GH	Greenland Halibut
GS	Greenland Shark
He	Herring
IN	Inconnu
LC	Least Cisco
PC	Polar Cod
Re	Redfish
Sa	Salmon
SC	Saffron Cod
Sc	Sculpin
Sm	Smelt
WF	Witch Flounder
Wh	Whitefish

○ - Spill Site

KEYS TO THE USE OF MAP SYMBOLS (CONT'D.)

5. Hunting and Fishing

AF - Arctic Fox
BW - Beluga Whale
F - Fish
PB - Polar Bear
RS - Ringed Seal
S - Seals (all species)
Sb - Seabirds
W - Whales
Wf - Waterfowl
WL - Walrus

- Spill Site

6. Hypothetical Slick Movement

- Spill Site
- Wind Direction
- Current Direction
25 - Mean Value (cm/sec)
(25) - Maximum Value (cm/sec)
- Tidal Current
 - Preferred Direction
1-3/10 - Fraction of Ice Cover

PREFACE

The following text and maps represent summaries of existing environmental information for each of the nine hypothetical spill sites considered in this study. The information for each site has been organized by topics as:

- Plankton/Invertebrates
- Seabirds
- Marine Mammals
- Fishery Resources
- Hunting and Fishing
- Hypothetical Slick Trajectory

Where the level of detail permits, the data are presented as pertaining to the open-water season or ice-covered season. The level of information for plankton and invertebrates in particular was generally insufficient to allow accurate distribution mapping. Contours plotted often represent areas inferred from physical data, e.g., production concentrated at ice edges. Other mapped points are typically reflective of site specific sampling and are not necessarily unique sites of biological activity. The seabird classification includes all marine associated birds: true seabirds and waterfowl. Information is presented in point form and is intended to accompany appropriate figures. Abbreviations used on maps are explained in the accompanying key.

Sources of information have not been specifically referenced in the following text. Reference material used in the preparation of the information summaries is listed by resource group in Section 6 of the report. Specific acknowledgement is given to the earlier information mapping effort, "An Arctic Atlas" (FENCO CONSULTANTS LTD. and F.F. Slaney & Co. Ltd., 1978), the entire series of reports generated as part of the Beaufort Sea Project, and the environmental studies generated for Lancaster Sound.

Hypothetical slick trajectories were calculated for crude oil spills of 30, 300, 3,000 and 30,000 m^3 at each site. Impact predictions presented in Section 4 of the report addressed the consequences of a 30,000 m^3 spill.

SITE 1: MACKENZIE BAY

Both the ice-covered and open-water periods have been mapped for this site.

Pl
- Transition zone between pack ice and landfast ice provides variable amounts of open-water through winter and spring.
- Localized area of phytoplankton production at this transition zone in spring.

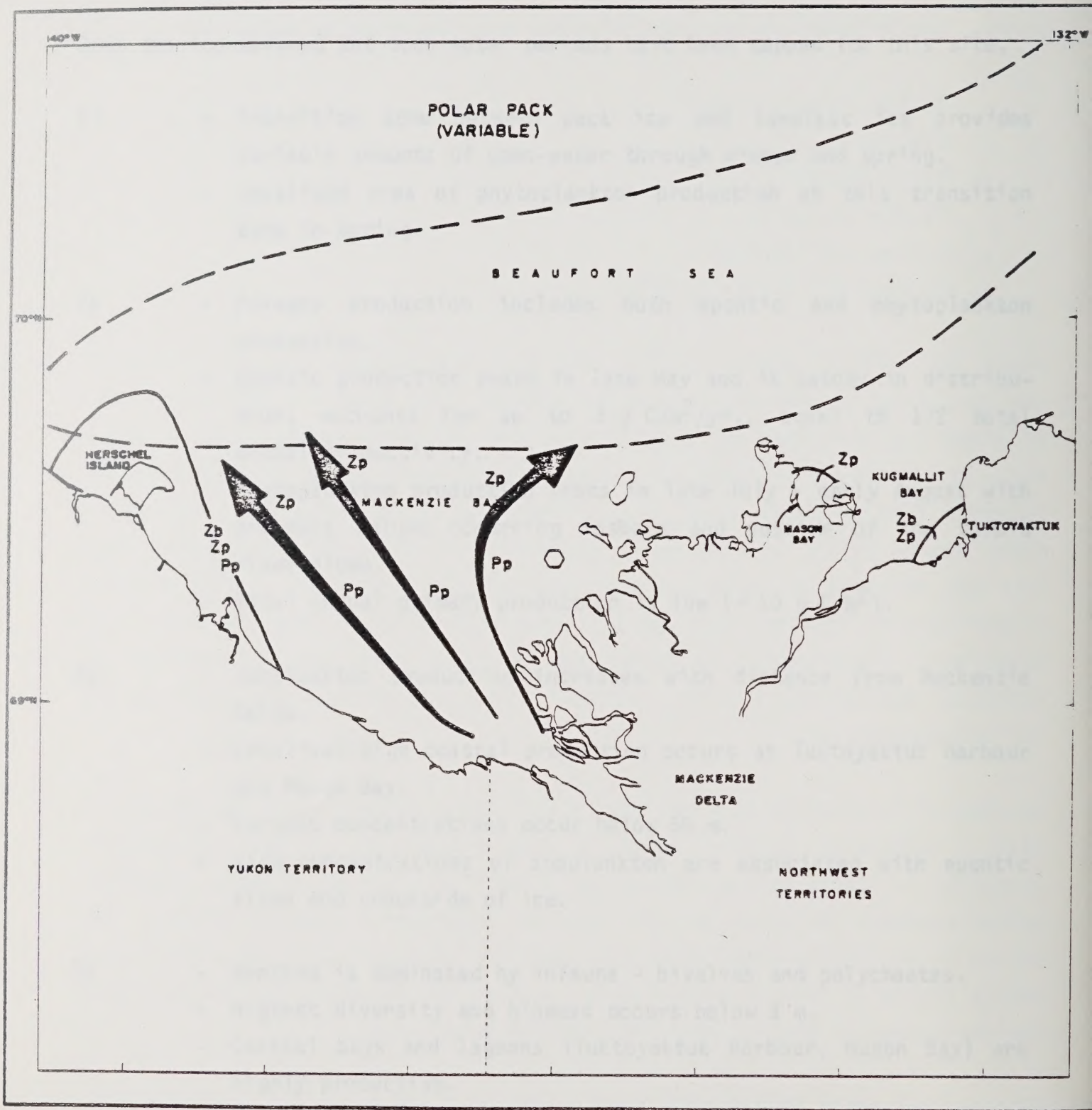
Pp
- Primary production includes both epontic and phytoplankton production.
- Epontic production peaks in late May and is patchy in distribution; accounts for up to 5 g $C/m^3/yr.$, equal to 1/2 total annual productivity.
- Phytoplankton production peaks in late July - early August with greatest values occurring inshore and outside of the turbid river plume.
- Total annual primary production is low ($\simeq$ 10 g C/m^2).

Zp
- Zooplankton production increases with distance from Mackenzie Delta.
- Localized high coastal production occurs at Tuktoyaktuk Harbour and Mason Bay.
- Largest concentrations occur below 50 m.
- High concentrations of zooplankton are associated with epontic algae and underside of ice.

Zb
- Benthos is dominated by infauna - bivalves and polychaetes.
- Highest diversity and biomass occurs below 3 m.
- Coastal bays and lagoons (Tuktoyaktuk Harbour, Mason Bay) are highly productive.
- Area of high species diversity occurs off Herschel Island.
- Benthic diversity and biomass are reduced in Mackenzie River plume.

- Coastal waters southeast of Herschel Island are most productive area on this map sheet.

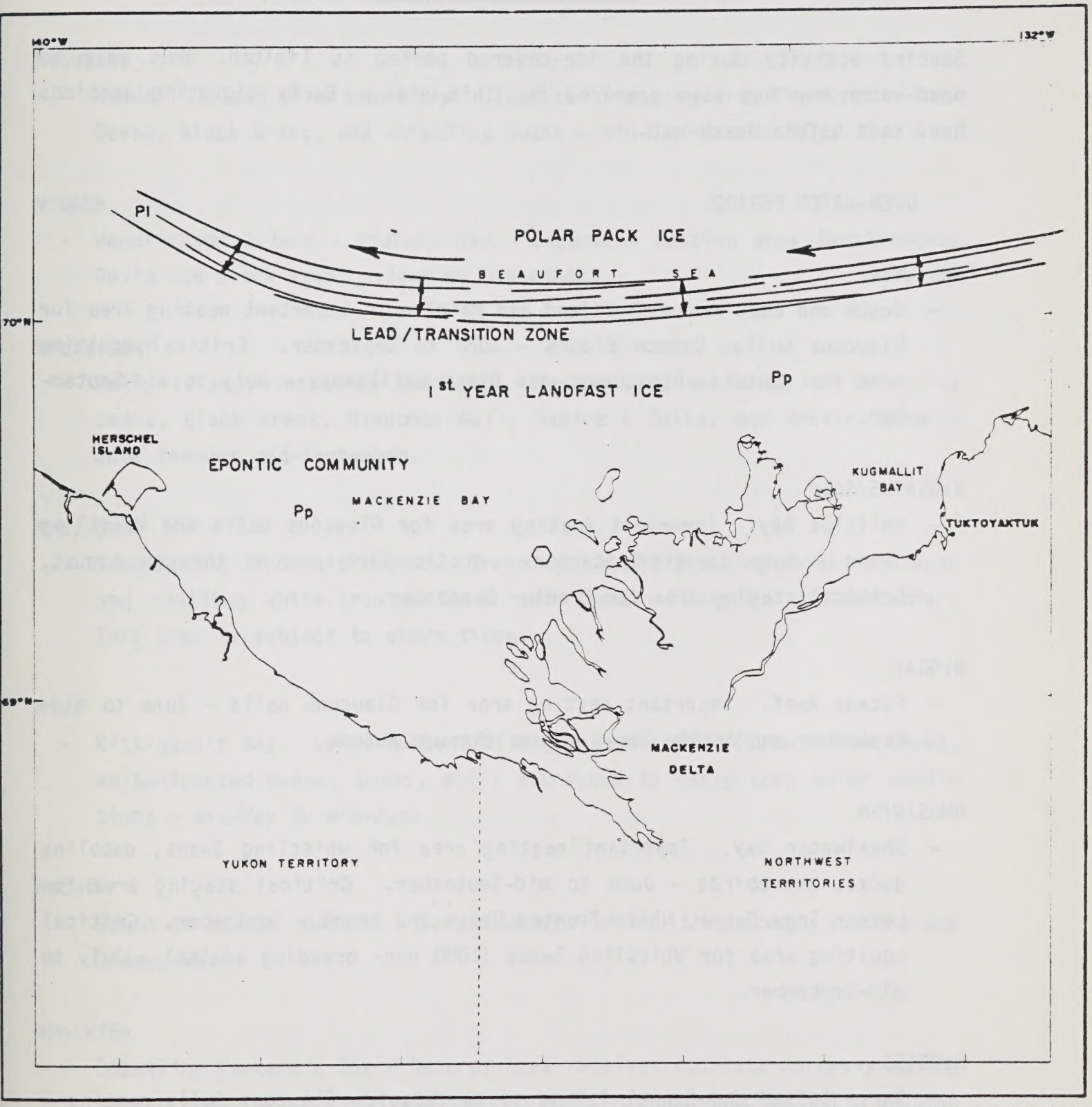
PLANKTON / INVERTEBRATES



SITE I : MACKENZIE BA
OPEN-WATER PERIOD

FIG. B.I

PLANKTON/INVERTEBRATES



SITE 1 : MACKENZIE BAY
ICE - COVERED PERIOD

FIG. B.2

SEABIRDS

SITE 1: MACKENZIE BAY

Seabird activity during the ice-covered period is limited; thus only an open-water map has been prepared for this site. Early migrating seabirds head east before break-up.

OPEN-WATER PERIOD

NMo:WfBG

- South and east Herschel Island and Mainland. Important nesting area for Glaucous Gulls, Common Eiders - June to September. Critical moulting area for scoters, Oldsquaws, and Black Guillemots - July to mid-September.

N:GGATWS/S:Br

- Phillips Bay. Important nesting area for Glaucous Gulls and Whistling Swans - June to mid-September. Arctic Tern - June through August. Critical staging area for brant - September.

N:GGAT

- Escape Reef. Important nesting area for Glaucous Gulls - June to mid-September and Arctic Terns - June through August.

NMoS:WfSh

- Shealwater Bay. Important nesting area for Whistling Swans, dabbling ducks, shorebirds - June to mid-September. Critical staging area for Lesser Snow Geese, White-fronted Geese and brant - September. Critical moulting area for Whistling Swans (1000 non- breeding adults) - July to mid-September.

N:GG(1)

- Garry Island and Gravel Island to northeast. Glaucous Gulls nesting - June to September.

N:GG(2)

- Hooper Island. Spits used by up to 85 pairs nesting Glaucous Gulls - June to September.

N:SNBBWS

- Kendall Island Bird Sanctuary. Important nesting area for Lesser Snow Geese, Black Brant, and Whistling Swans - mid-May to mid-July.

N:GGBB

- Hendrickson Island - Kidluit Bay. Important nesting area for Glaucous Gulls and Black Brant - June to September.

NMo:WfGuAT

- Pelly Island, including sandspit. Nesting and moulting for Whistling Swans, Black Brant, Glaucous Gull, Sabine's Gulls, and Arctic Terns - June through mid-September.

NMo:WSWG

- Swan Channel - Dennis Lagoon. Breeding and non-breeding Whistling Swans and moulting White-fronted Geese and swans - June to mid-September. This area is subject to storm tides.

M:Wf

- Kittigazuit Bay. Large numbers of migrant waterfowl (Lesser Snow Geese, White-fronted Geese, swans, etc.) attracted to early open water conditions - mid-May to mid-June.

Mo:Wf

- South of Hansen Harbour. Large numbers of moulting scaup, scoters and Oldsquaws.

NMo:WfSh

- Coastline Mackenzie Bay - General area receives moderate to heavy use by swans, geese and shorebirds, particularly during moulting and migration periods (mid-summer through September). When sea ice is clear the area is subjected to storm tides.

MMo:WfGu

- Tuktoyaktuk Peninsula. Extensive coastline frequented by large numbers of waterfowl. Lesser Snow Geese, brant, eiders, gulls, jaegers, loons, etc. migration mid-May to mid-June and mid-August to mid-September. Oldsquaws, scaup and scoters moult July-August.

Ms:WfGuAT

- North of Tuktoyaktuk Peninsula. Spring migration route for hundreds of thousands eiders, Oldsquaws, brant, loons, Glaucous Gulls, jaegers, and Arctic Terns.

Ms:SN

- Spring migration route for Snow Geese.

Ms:WfSh(1)

- Westerly migration largely of Whistling Swans, White-fronted Geese, Pintails, and shorebirds mid-May until late June, although other species may also be involved in this early period. Westward migration in early July is largely scoters and Oldsquaws. Scoters form a broad-front migration along with Pintails and other species. Variation, especially in numbers of Pintails, occurs relative to changes in breeding ground conditions.

Ms:WfSh(2)

- Broad-front northeastern migration. Species composition and numbers are poorly defined, although it is suspected that brant, Oldsquaws or shorebirds comprise the bulk of the birds.

Ms:Sb

- Broad-front offshore migration route from Bering and Chukchi Seas to open water further east. (e.g., Banks Island). Two million sea-birds of 10 species migrate offshore using leads between landfast and pack ice. Large numbers also migrate at high altitudes. Migrations begin late April - early May, with peak reached in late May. Large migrations further offshore are also likely.

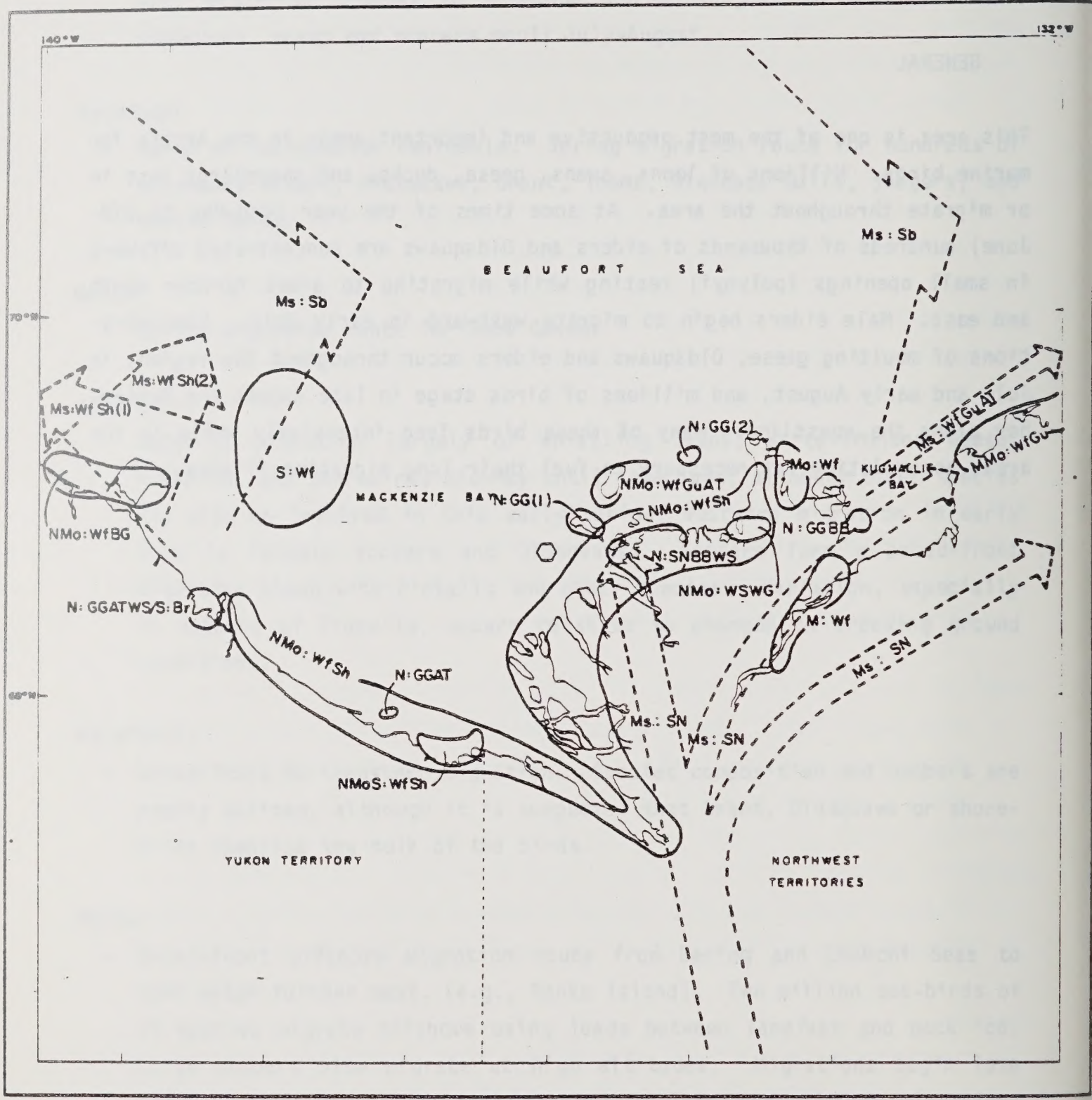
S:Wf

- Offshore - Mackenzie Delta. Thousands of Oldsquaws, eiders and loons were concentrated in open-water in early June 1974, suggesting this area is an important spring migration stopover when free of ice.

GENERAL

This area is one of the most productive and important areas in the Arctic for marine birds. Millions of loons, swans, geese, ducks, and shorebirds nest in or migrate throughout the area. At some times of the year (mid-May to mid-June) hundreds of thousands of eiders and Oldsquaws are concentrated offshore in small openings (polynyi) resting while migrating to areas further north and east. Male eiders begin to migrate westward in early July. Concentrations of moulting geese, Oldsquaws and eiders occur throughout the region, in July and early August, and millions of birds stage in late August and September along the coastline. Many of these birds feed intensively while in the area, accumulating fat necessary to fuel their long migration flights.

SEABIRDS



SITE I : MACKENZIE BAY
OPEN-WATER PERIOD

FIG. B.3

MARINE MAMMALS

SITE 1: MACKENZIE BAY

Both open-water and ice-covered periods have been mapped for this site.

OPEN-WATER PERIOD:

Ms:BW - 4,000 to 6,000 beluga whales arrive in late June via the nearshore lead.

G:BW - 4,000 to 6,000 beluga whales summer in the southeast Beaufort Sea near the coast.

R:BW - 600 to 700 calves are born each year in or near these concentration areas where the warmer water is important for newborn calves.
- Feeding appears to be unimportant in the calving areas.

Mf:BW - Large numbers of beluga whales (> 2,000) move westwards along the coast in September.
- The number of beluga whales migrating via offshore waters is not known.

F:BH - Small numbers of bowhead whales are sighted each year, apparently feeding in this area during early September.

Mf:BH - Small numbers of bowhead whales (≈ 50) pass westwards within 20 km of the coast during late August - early September.
- The number of bowhead whales migrating via offshore waters is not known.

G:RS - Sub-adult ringed seals summer in the offshore waters.

G:PB - Polar bears retreat northwards in association with the pack ice, as the summer progresses.

- Relatively small numbers remain along the coast during the open-water period.

ICE-COVERED PERIOD:

G:RS
- Ringed seals (adolescents and adults) are abundant in this zone surrounding the floe edge due to the abundance of leads (open or refrozen) which are used for breathing holes. Used from mid-October to mid-May.

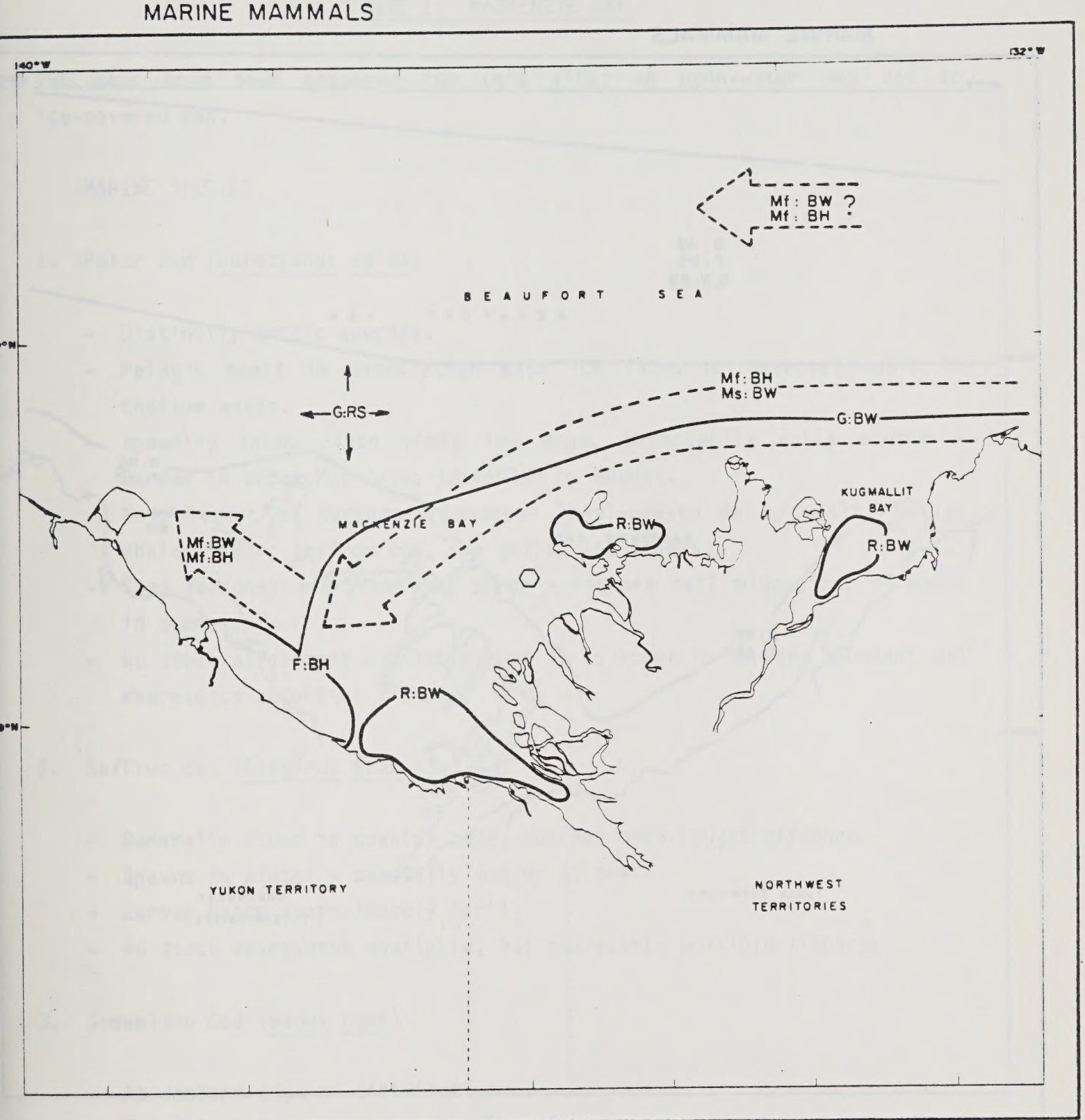
F:PB
- The floe edge area is critical feeding territory for polar bear, especially in years when seal numbers and reproductive success in fast-ice areas are low. Used from mid-October to mid-May.
- Abundance varies from 0.9 to 1.5 bears per 100 km.
- Denning frequency is low along the mainland coast and few bears occupy landfast ice.

G,R:BS
- Bearded seal pupping is concentrated in this area of open or refrozen leads in late April; an important overwintering area for all bearded seals.

R:RS
- Ringed seal pupping areas are widely dispersed through the fast ice areas, mainly in the large bays and to a lesser degree in the inshore fast-ice areas off the Tuktoyaktuk Peninsula.
- Late March to early April.
- 2-month weaning period.

F:AF
- Arctic fox scavenge along the coast feeding on marine mammal carcasses during the winter.
- The offshore lead system may be important for arctic fox as a feeding area (scavenge at bear kills).

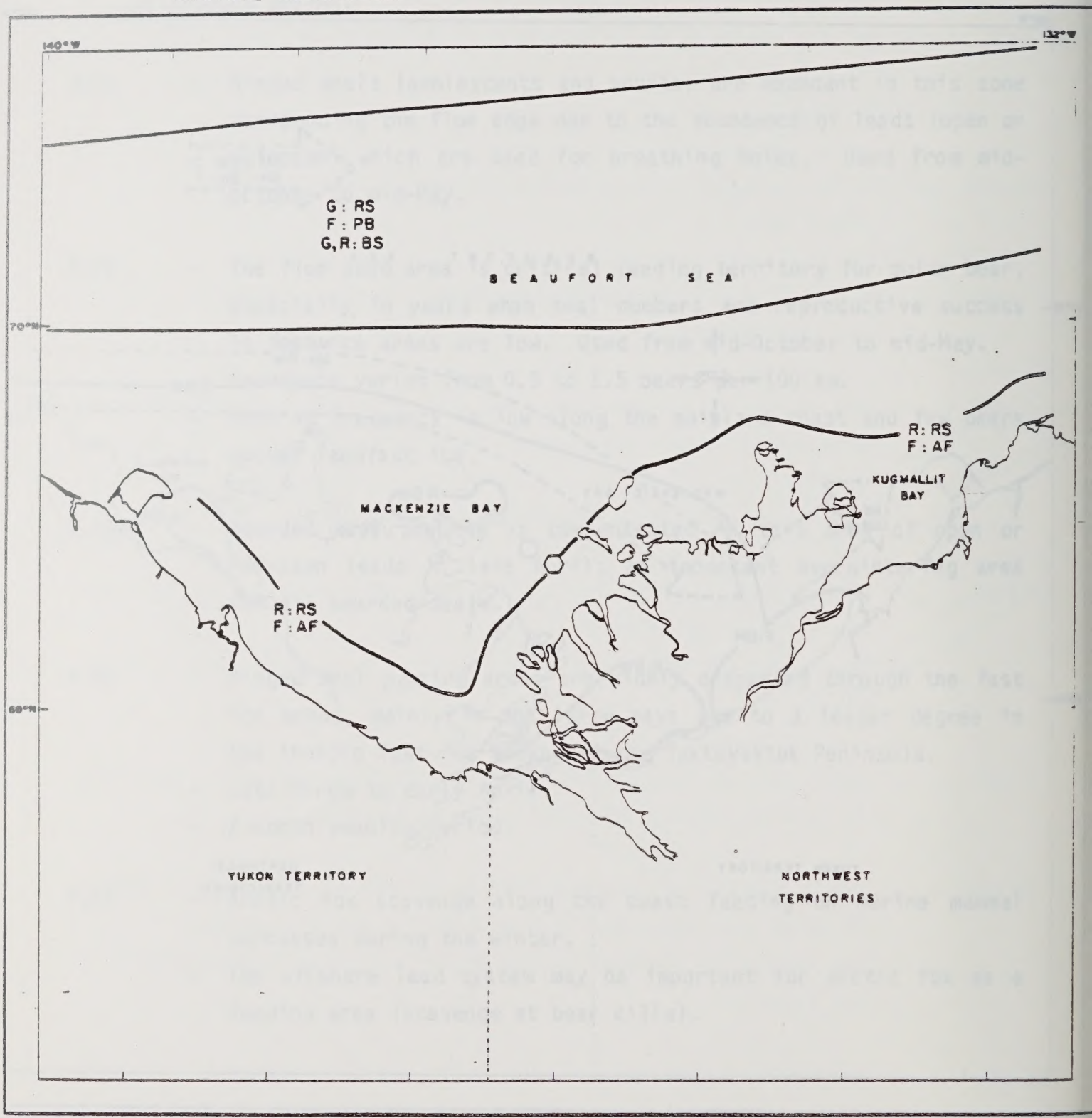
MARINE MAMMALS



SITE I : MACKENZIE BAY
OPEN-WATER PERIOD

FIG. B.4

MARINE MAMMALS



SITE I : MACKENZIE BA
ICE - COVERED PERIOD

FIG. B.5

FISHERY RESOURCES

SITE 1: MACKENZIE BAY

Two maps have been prepared for this site; an open-water map and an ice-covered map.

MARINE SPECIES

1. Polar Cod (Boreogadus saida)

- Distinctly arctic species.
- Pelagic habit in association with ice floes or demersal habit in shallow water.
- spawning takes place along ice edge, principally early winter - larvae in water May-July; juveniles by August.
- Key element of secondary consumer level-preyed on by seals, beluga whales, char, saffron cod, sea gulls, and others.
- Some seasonal migration may occur - inshore fall migration, offshore in summer.
- No stock assessment available, but it is known to be very abundant and represents potential fishery.

2. Saffron cod (Eleginus gracilis)

- Generally found in coastal zone, but has been caught offshore.
- Spawns in winter - coastally and/or at sea.
- Larvae hatch approximately April.
- No stock assessment available, but represents possible fishery.

3. Greenland Cod (Gadus ogac)

- At western edge of distribution.
- Found in inlets and bays, rarely offshore.
- Abundance is small, except possibly for a large concentration in Coronation Gulf.

- Of no commercial importance. Future importance questionable due to patchy and limited distribution.

4. Arctic flounder (Liopsetta glacialis)

- Demersal species found in brackish coastal waters and occasionally in lower reaches of Mackenzie and other rivers.
- Of no commercial value at present, may represent potential fishery.

5. Starry flounder (Platichthys stellatus)

- Coastal demersal fish, often found in freshwater; limited migration.
- May be found down to 300 m.
- Spawning information lacking, but does not breed in fresh water.
- Occasionally fished, but not the object of any fishery.

6. Herring (Clupea harengus pallasii)

- Abundant coastally and in river mouths.
- Annual spring spawners. Eggs are demersal, but little information on larvae available. Juveniles are believed to move out to sea during their first winter.
- Object of a domestic gillnet, weir, trap, and seine fishery in this area. Potential exists for increased fishery.

7. Capelin (Mallotus villosus)

- Abundance unknown and unpredictable.
- Are known to spawn in summer on beaches, in particular, Herschel Island, but not known if spawning occurs offshore as in eastern Canada.
- Taken in seines when abundant.
- Represents potential fishery if stocks warrant.

8. Fourhorn sculpin (Myoxocephalus quadricornis)

- Abundant demersal fish.
- No commercial value.
- Has freshwater and marine populations.

ANADROMOUS SPECIES

1. Whitefish (Coregonidae)

- Five major species found in this area:
  - Coregonus nasus (broad whitefish)
  - C. autumnalis (arctic cisco)
  - C. sardinella (least cisco)
  - C. clupeaformis (lake whitefish)
  - Stenodus leucichthys (inconnu)
- All species exhibit upstream spawning runs in spring and summer.
- Migrate downstream after spawning but usually before freeze-up.
- Information on juveniles limited.
- Fry generally move downstream after one or two years.
- Important food source for larger fish, particularly lake trout, pike, burbot, and other whitefish.
- Was important to commercial fisheries in the area, especially broad and lake whitefish and inconnu. Broad whitefish comprised up to 72% of total catches. Also important as a sportfishery. Used now for domestic purposes, especially arctic cisco.
- Fished by gillnets during fall and/or spring runs. Lake whitefish also the object of a winter fishery and arctic cisco and broad whitefish often taken in a summer fishery.
- Prosopium cylindroceum (round whitefish) also found in this area, but in reduced numbers. Exhibits fall spawning migration.

2. Smelt (Osmerus mordax)

- Pelagic marine species which migrates upstream during spring (often before break-up).
- Important as a food source for lake trout, burbot, smelt and sea gulls.
- Plentiful in this area.
- Represents potential fishery.

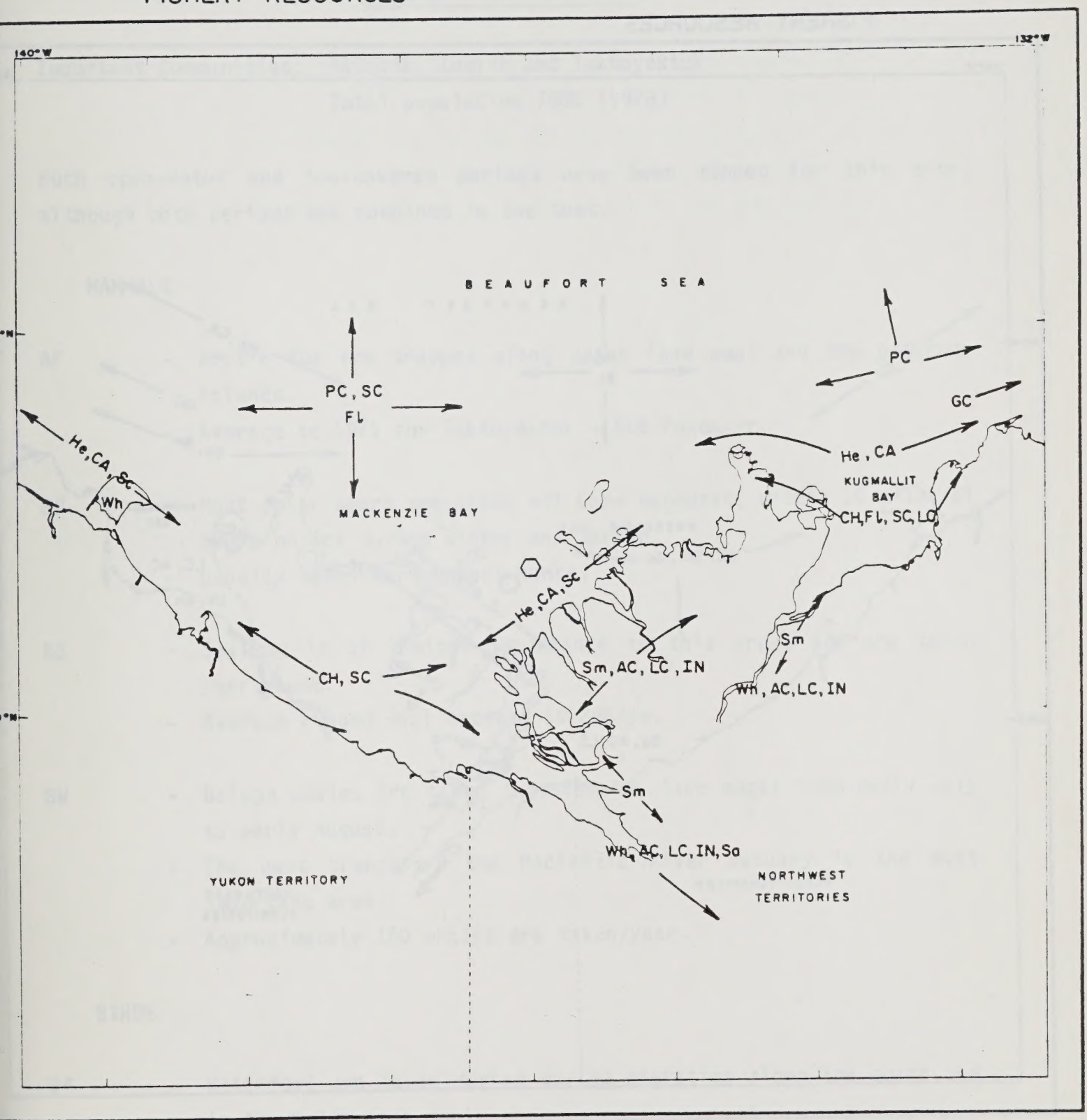
3. Arctic char (Salvelinus alpinus)

- Runs to sea in spring to feed.
- Returns to rivers and streams in late summer/fall to spawn.
- Slow growing fish.
- Eggs incubate overwinter; smolts remain in rivers and lakes for 5-7 years before running to sea (150-200 mm length).
- Fished domestically by gillnets, traps and spears during summer and the fall run. May also be fished in sea surrounding southern Banks Island.
- Important also for sportfishing.
- Important food source for man, terns, loons, char and seals.

4. Chum salmon (Oncorhynchus keta)

- Spends most of time at sea.
- Ascends Mackenzie River late summer to spawn; dies without returning to sea.
- Eggs hatch in winter, alevins descend to sea during first spring.
- Important prey to other fish, predaceous seabirds and mammals.
- Fished incidentally in whitefish fishery.

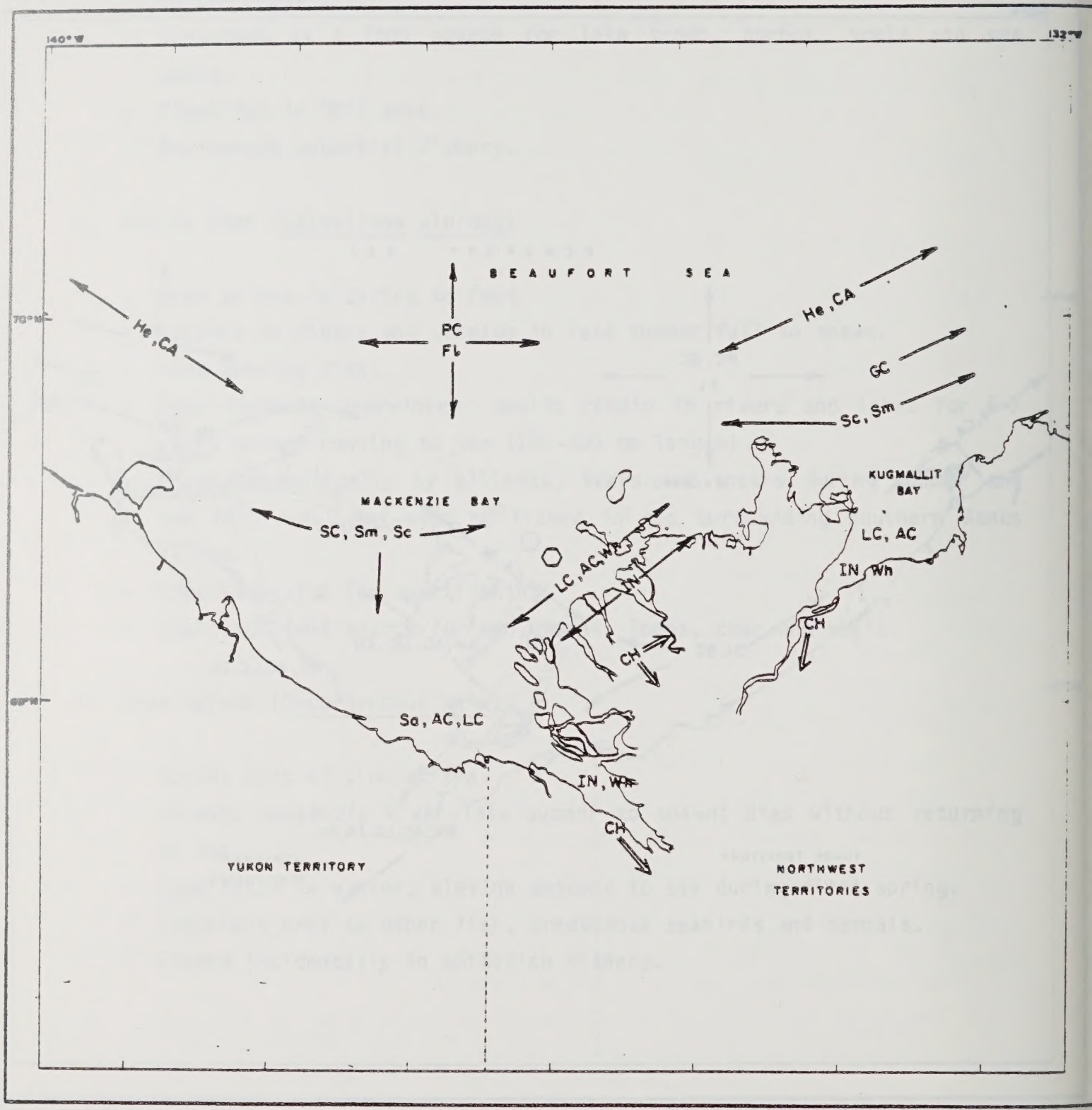
FISHERY RESOURCES



SITE 1 : MACKENZIE BAY
OPEN - WATER PERIOD

FIG. B.6

FISHERY RESOURCES



SITE I : MACKENZIE BAY
ICE-COVERED PERIOD

FIG. B.7

HUNTING AND FISHING

SITE 1: MACKENZIE BAY

Important Communities: Aklavik, Inuvik and Tuktoyaktuk
Total population 7500 (1978)

Both open-water and ice-covered periods have been mapped for this site, although both periods are combined in the text.

MAMMALS

AF
- Arctic fox are trapped along coast (see map) and the offshore inlands.
- Average to 1971 for Tuktoyaktuk - 518 foxes/yr.

PB
- Most polar bears are taken off Cape Bathurst, within 10 miles of shore on ice during winter and spring.
- Usually taken during seal hunts.

RS
- Sealing is of limited importance to this area, but are taken year round.
- Average ringed seal harvest is 286/yr.

BW
- Beluga whales are taken in estuaries (see maps) from early July to early August.
- The east branch of the Mackenzie River estuary is the most important area.
- Approximately 150 whales are taken/year.

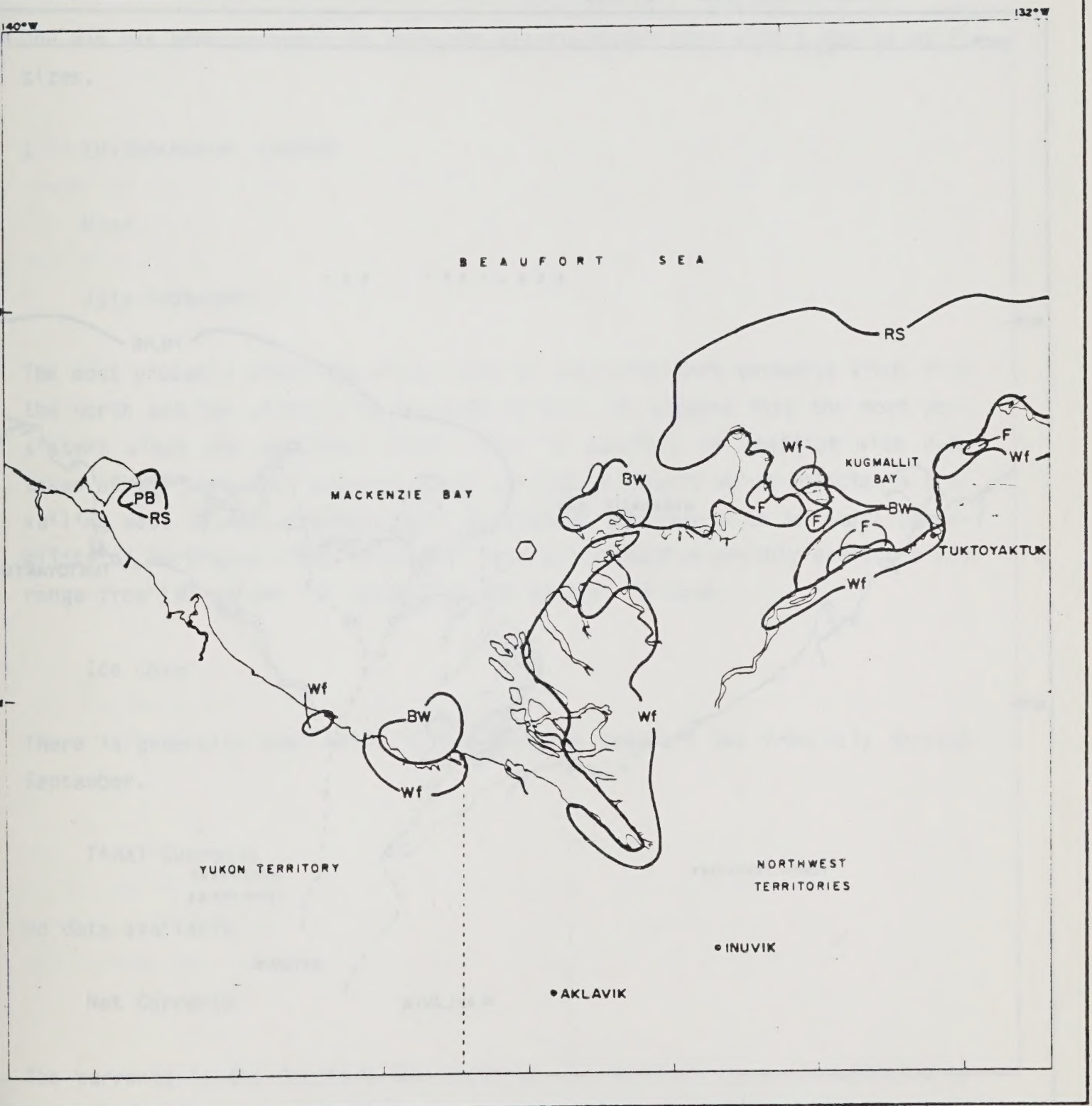
BIRDS

Wf
- Waterfowl are taken during spring migration along the coast and in the Delta (see map).

FISHERIES

Ff

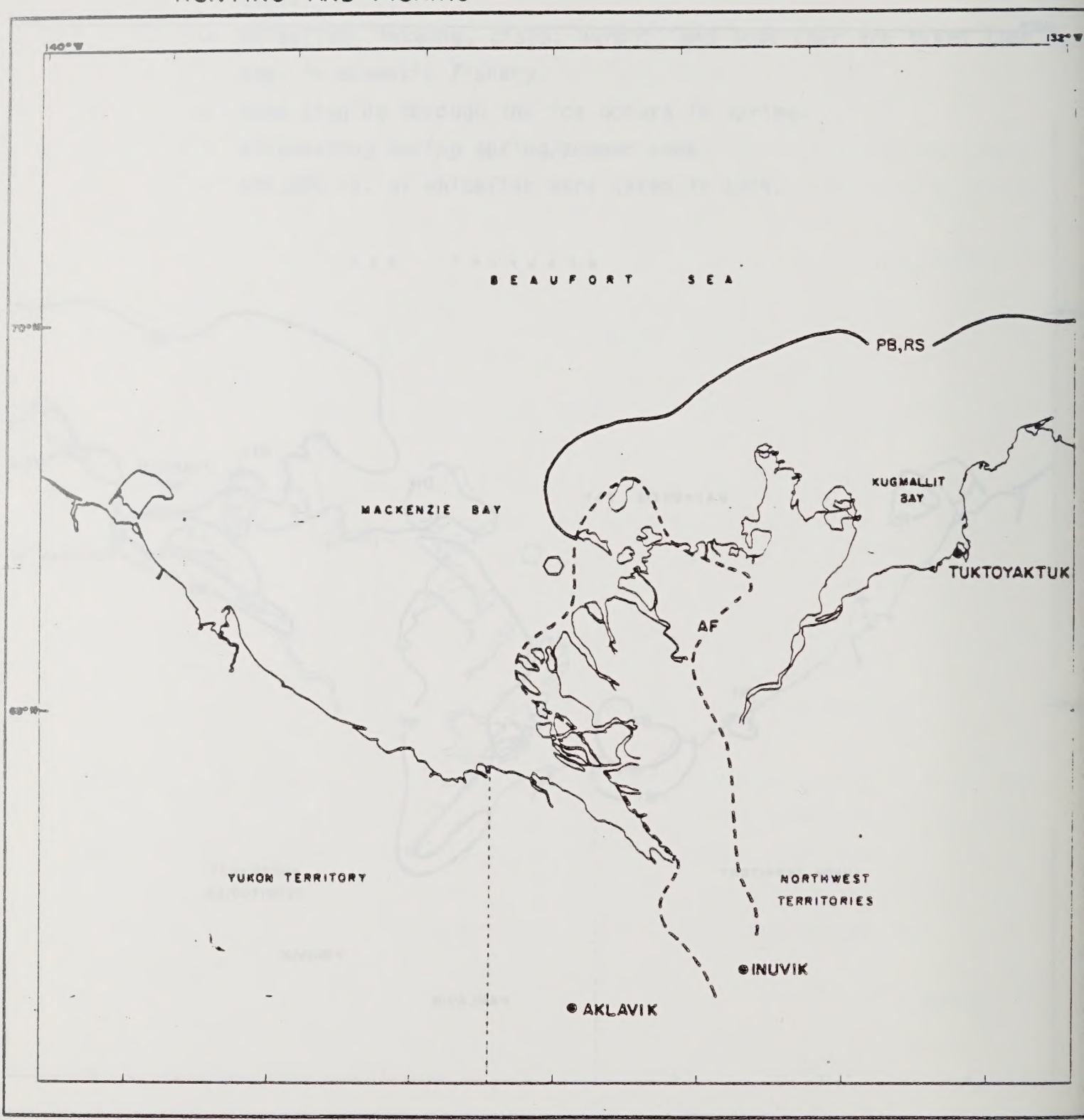
- Commercial ciscoe and whitefish fishery has been closed since 1979.
- Whitefish, inconnu, cisco, burbot, and some char are taken (see map) in domestic fishery.
- Some jigging through the ice occurs in spring.
- Gillnetting during spring/summer runs.
- 185,000 lb. of whitefish were taken in 1974.



SITE I : MACKENZIE BAY
OPEN-WATER PERIOD

FIG. B.8

HUNTING AND FISHING



SITE I : MACKENZIE BA
ICE - COVERED PERIOD

FIG. B.9

HYPOTHETICAL SLICK MOVEMENT

SITE 1: MACKENZIE BAY

One map has been prepared to show the environmental data with a key to spill sizes.

I ENVIRONMENTAL SUMMARY

Wind

July-September

The most probable winds are either east or west with more probable winds from the north and low probability of south winds. It appears that the most persistent winds are northwest winds. This is possibly in conflict with data taken at the permanent meteorological station at Inuvik which indictes a prevailing east to eastnortheast wind throughout the year with an equal probability of Northwest winds in summer. The all direction monthly average winds range from 190 cm/sec. in January to 360 cm/sec. in June.

Ice Cover

There is generally open water in the southern Beaufort Sea from July through September.

Tidal Currents

No data available.

Net Currents

The currents in the Beaufort Sea south of the Beaufort Gyre are affected by many factors whose interaction is poorly understood. The most prominent factors are the fresh water inflow of the Mackenzie River and the wind. The

predominant current in the southern Beaufort Sea is northeast. However, an east wind of a few days may reverse the current to the northwest.

II SURFACE SLICK

Trajectory

The prevailing wind and the subsequent pattern of wind induced currents would suggest that the most likely trajectory would be to the northeast. The group of islands 10-20 km to the northeast would very likely be impacted. It is, however, possible that a prevailing wind from the east at the time of the spill would cause drift out into the more open waters of Mackenzie Bay.

30 m^3 - Surface extent is small relative to the open water features in the area but could be significant in terms of the smaller coastline features. This effect is enhanced by the site's proximity to the coast.

300 m^3 - Small in scale relative to the open water areas but of the same scale as the islands to the northeast and most of the coastal features.

3,000 m^3 - Large in scale with respect to the islands and most of the coastal features but still small relative to the size of Mackenzie Bay.

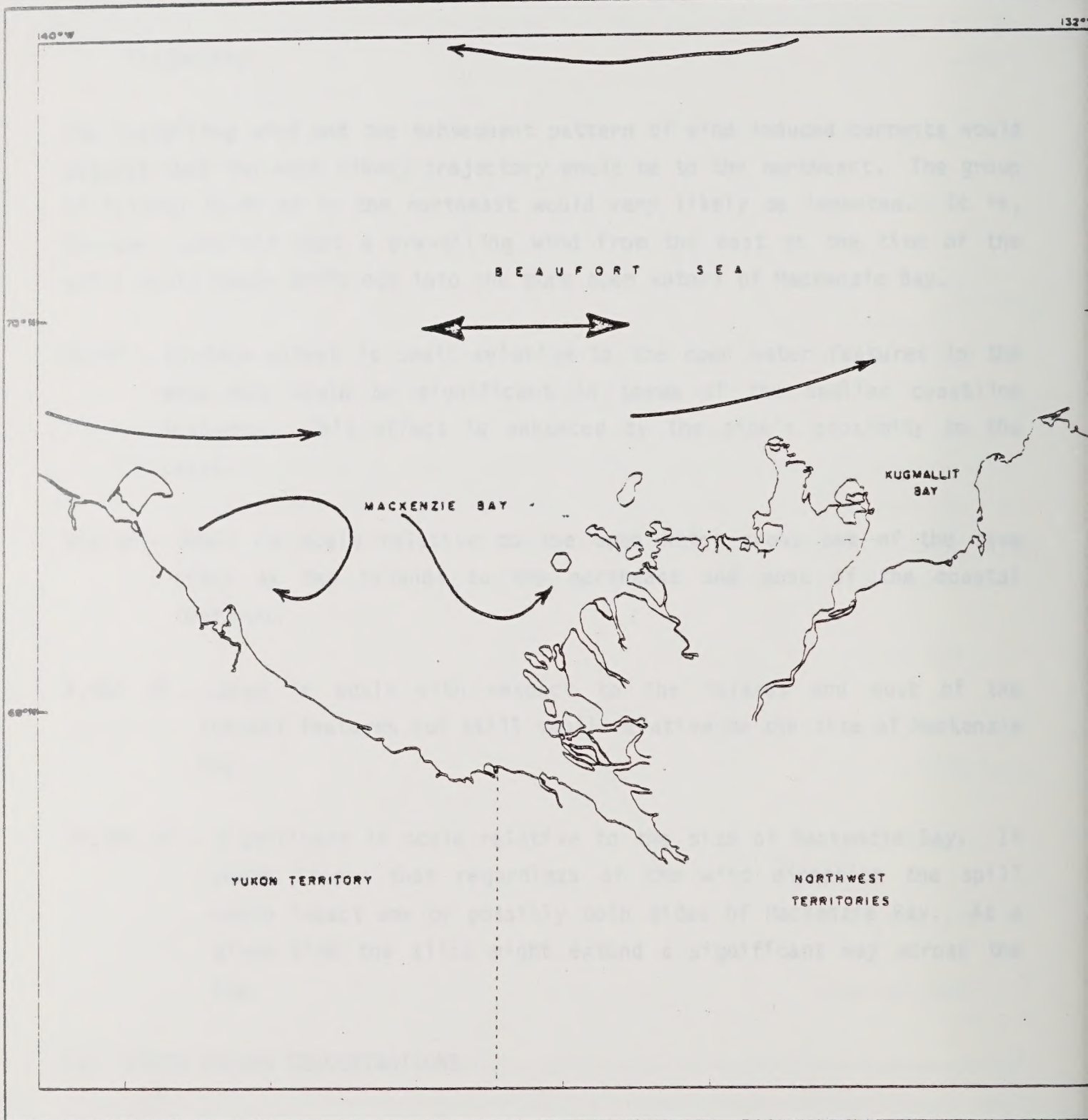
30,000 m^3 - Significant in scale relative to the size of Mackenzie Bay. It seems likely that regardless of the wind direction the spill would impact one or possibly both sides of Mackenzie Bay. At a given time the slick might extend a significant way across the Bay.

III WATER COLUMN CONCENTRATIONS

30-3,000 m^3 - Of significant size relative to coastal features.

30,000 m^3 - Large in scale relative to Mackenzie Bay; with the assumptions of 45% entrained to a depth of 10 m it would take more volume than Mackenzie Bay to dilute the oil below a 100 ppb concentration.

HYPOTHETICAL SLICK MOVEMENT



SITE I : MACKENZIE

Spill Volume	Slick Diameter	Diameter 100 ppb Contamination
30 m^3	1.8 km	4.1 km
300 m^3	5.6 km	13.0 km
3000 m^3	18 km	41 km
30000 m^3	45 km	130 km

FIG. B.10

SITE 2: BEAUFORT SEA

Both the ice-covered and open-water periods have been mapped for this site.

Pl
- Transition zone between pack ice and landfast ice provides variable amounts of open-water through winter and spring.
- Localized area of phytoplankton production at this transition zone in spring.

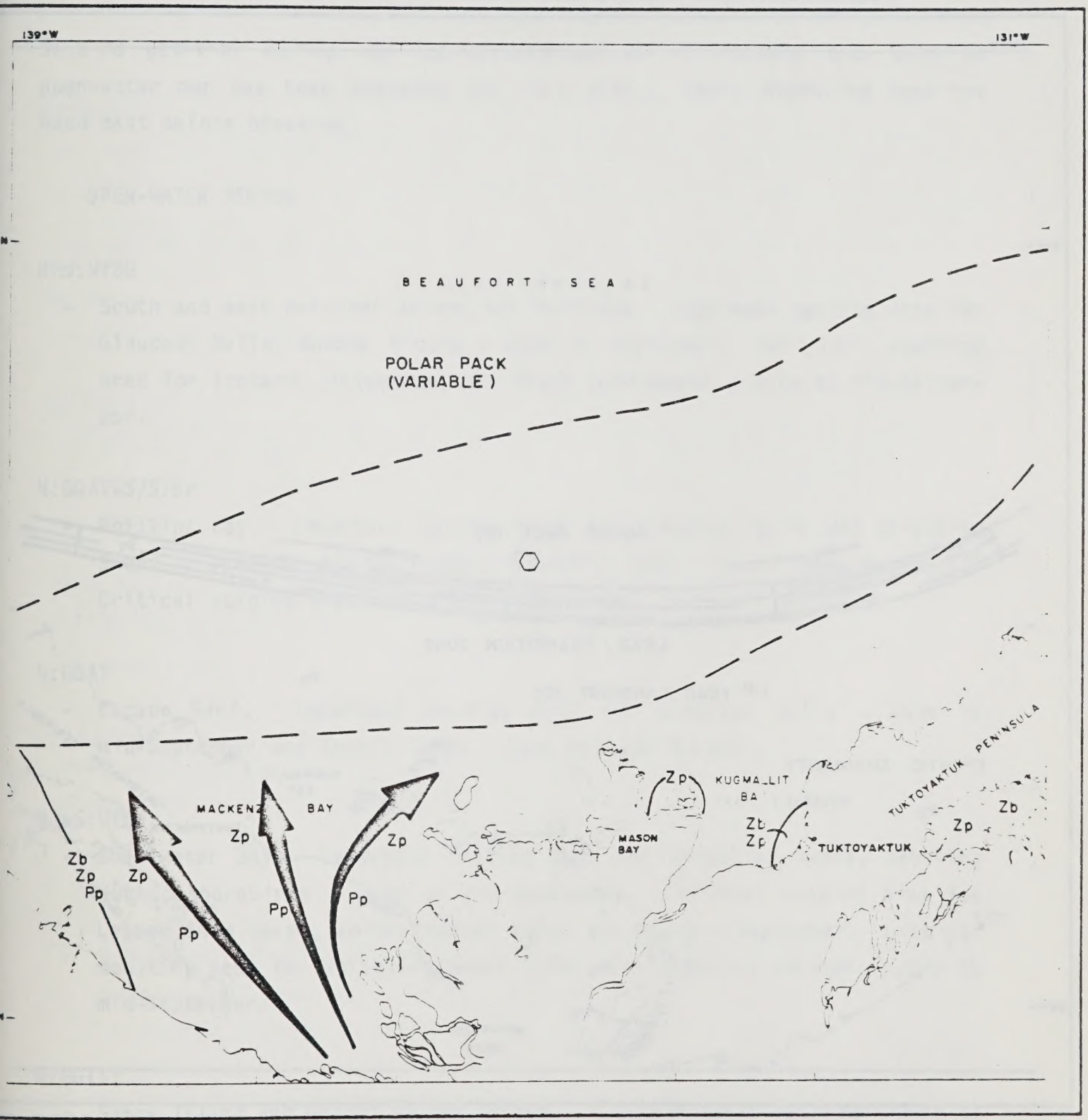
Pp
- Primary production includes both epontic and phytoplankton production.
- Epontic production peaks in late May and is patchy in distribution; accounts for up to 5 g $C/m^3/yr.$, equal to 1/2 total annual productivity.
- Phytoplankton production peaks in late July - early August with greatest values occurring inshore and outside of the turbid river plume.
- Total annual primary production is low ($\simeq 10$ g C/m^2).

Zp
- Zooplankton production increases with distance from Mackenzie Delta.
- Localized high coastal production occurs at Tuktoyaktuk Harbour and Mason Bay.
- Largest concentrations occur below 50 m.
- High concentrations of zooplankton are associated with epontic algae and underside of ice.

Zn
- Benthos is dominated by infauna - bivalves and polychaetes - highest diversity and biomass occurs below 3 m.
- Coastal bays and lagoons (Tuktoyaktuk Harbour, Mason Bay) are highly productive.
- Area of high species diversity occurs off Herschel Island.

- Benthic diversity and biomass are reduced in Mackenzie River plume.
- Coastal waters southeast of Herschel Island are most productive area on this map sheet.

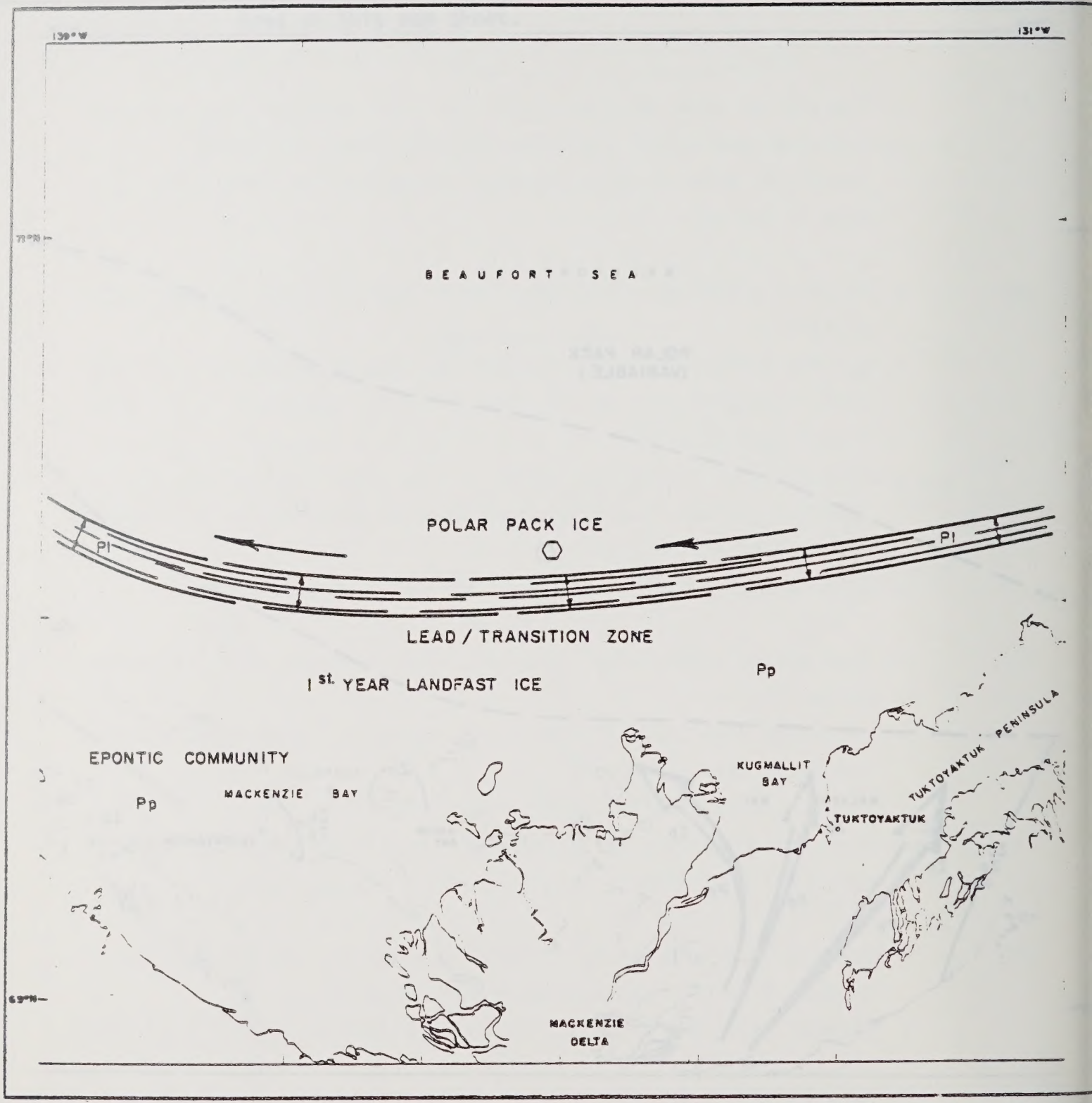
PLANKTON/INVERTEBRATES



SITE 2 : BEAUFORT SEA
OPEN-WATER PERIOD

FIG. B.11

PLANKTON / INVERTEBRATES



SITE 2 : BEAUFORT SEA
ICE - COVERED PERIOD

FIG. B.12

SEABIRDS

SITE 2: BEAUFORT SEA

Seabird activity during the ice-covered period is limited; thus only an open-water map has been prepared for this site. Early migrating seabirds head east before break-up.

OPEN-WATER PERIOD

NMo:WfBG

- South and east Herschel Island and Mainland. Important nesting area for Glaucous Gulls, Common Eiders - June to September. Critical moulting area for scoters, Oldsquaws, and Black Guillemots - July to mid-September.

N:GGATWS/S:Br

- Phillips Bay. Important nesting area for Glaucous Gulls and Whistling Swans - June to mid-September. Arctic Tern - June through August. Critical staging area for brant - September.

N:GGAT

- Escape Reef. Important nesting area for Glaucous Gulls - June to mid-September and Arctic Terns - June through August.

NMoS:WfSh

- Shealwater Bay. Important nesting area for Whistling Swans, dabbling ducks, shorebirds - June to mid-September. Critical staging area for Lesser Snow Geese, White-fronted Geese and brant - September. Critical moulting area for Whistling Swans (1000 non- breeding adults) - July to mid-September.

N:GG(1)

- Garry Island and Gravel Island to N/E. Glaucous Gulls nesting - June to September.

N:GG(2)

- Hooper Island. Spits used by up to 85 pairs nesting Glaucous Gulls - June to September.

N:SNBBWS

- Kendall Island Bird Sanctuary. Important nesting area for lesser snow geese, black brant, and whistling swans - mid-May to mid-July.

N:GGBB

- Hendrickson Island - Kidluit Bay. Important nesting area for glaucous gulls and black brant - June to September.

NMo:WfGuAT

- Pelly Island, including sandspit. Nesting and moulting for whistling swans, black brant, glaucous gull, Sabine's gulls, and Arctic terns - June through mid-September.

NMo:WSWG

- Swan Channel - Dennis Lagoon. Breeding and non-breeding whistling swans and moulting white-fronted geese and swans - June to mid- September. This area is subject to storm tides.

M:Wf

- Kittigazuit Bay. Large numbers of migrant waterfowl (lesser snow geese, white-fronted geese, swans, etc.) attracted to early open water conditions - mid-May to mid-June.

Mo:Wf

- South of Hansen Harbour. Large numbers of moulting scaup, scoters and oldsquaws.

NMo:WfSh

- Coastline Mackenzie Bay - General area receives moderate to heavy use by swans, geese and shorebirds, particularly during moulting and migration periods (mid-summer through September). When sea ice is clear the area is subjected to storm tides.

MMo:WfGu

- Tuktoyaktuk Peninsula. Extensive coastline frequented by large numbers of waterfowl. Lesser snow geese, brant, eiders, gulls, jaegers, loons, etc. migration mid-May to mid-June and mid-August to mid-September. Oldsquaws, scaup and scoters moult July-August.

Ms:WfGuAT

- North of Tuktoyuktuk Peninsula. Spring migration route for hundreds of thousands eiders, oldsquaws, brant, loons, glaucous gulls, jaegers, and Arctic terns.

Ms:SN

- Spring migration route for snow geese.

Ms:WfSh(1)

- Westerly migration largely of whistling swans, white-fronted geese, pintails, and shorebirds mid-May until late June, although other species may also be involved in this early period. Westward migration in early July is largely scoters and oldsquaws. Scoters form a broad-front migration along with pintails and other species. Variation, especially in numbers of pintails, occurs relative to changes in breeding ground conditions.

Ms:WfSh(2)

- Broad-front northeastern migration. Species composition and numbers are poorly defined, although it is suspected that brant, oldsquaws or shorebirds comprise the bulk of the birds.

Ms:Sb

- Broad-front offshore migration route from Bering and Chukchi Seas to open-water further east. (e.g., Banks Island). Two million seabirds of 10 species migrate offshore using leads between landfast and pack ice. Large numbers also migrate at high altitudes. Migrations begin late April - early May, with peak reached in late May. Large migrations further offshore are also likely.

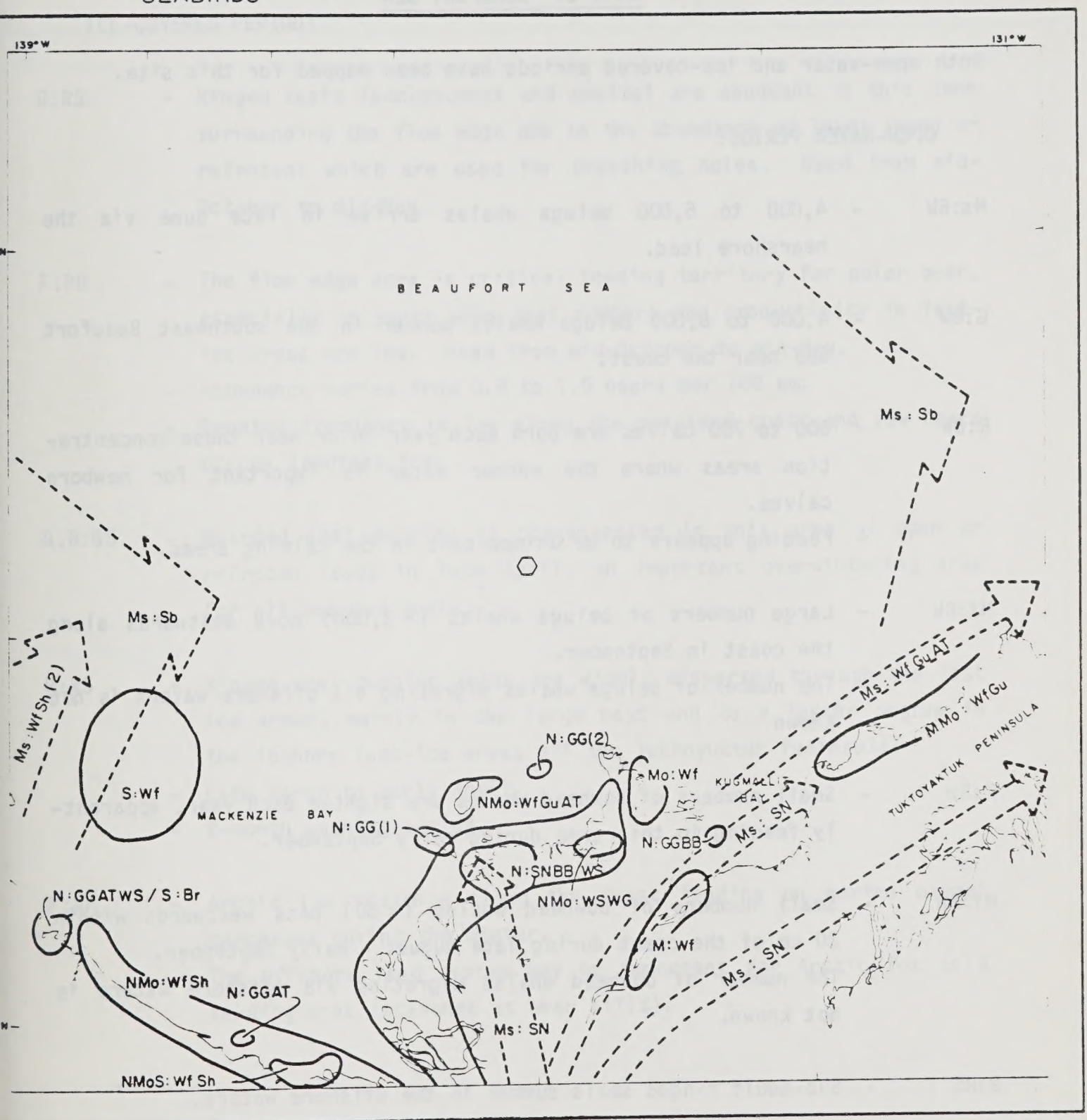
S:Wf

- Offshore - Mackenzie Delta. Thousands of oldsquaws, eiders and loons were concentrated in open-water in early June 1974, suggesting this area is an important spring migration stopover when free of ice.

GENERAL

This area is one of the most productive and important areas in the Arctic for marine birds. Millions of loons, swans, geese, ducks, and shorebirds nest in or migrate throughout the area. At some times of the year (mid-May to mid-June) hundreds of thousands of eiders and Oldsquaws are concentrated offshore in small openings (polynyi) resting while migrating to areas further north and east. Male eiders begin to migrate westward in early July. Concentrations of moulting geese, Oldsquaws and eiders occur throughout the region, in July and early August, and millions of birds stage in late August and September along the coastline. Many of these birds feed intensively while in the area, accumulating fat necessary to fuel their long migration flights.

SEABIRDS



SITE 2 : BEAUFORT SEA
OPEN - WATER PERIOD

FIG. B.13

SITE 2: BEAUFORT SEA

Both open-water and ice-covered periods have been mapped for this site.

OPEN-WATER PERIOD:

Ms:BW - 4,000 to 6,000 beluga whales arrive in late June via the nearshore lead.

G:BW - 4,000 to 6,000 beluga whales summer in the southeast Beaufort Sea near the coast.

R:BW - 600 to 700 calves are born each year in or near these concentration areas where the warmer water is important for newborn calves.
- Feeding appears to be unimportant in the calving areas.

Mf:BW - Large numbers of beluga whales (> 2,000) move westwards along the coast in September.
- The number of beluga whales migrating via offshore waters is not known.

F:BH - Small numbers of bowhead whales are sighted each year, apparently feeding in this area during early September.

Mf:BH - Small numbers of bowhead whales (≈ 50) pass westwards within 20 km of the coast during late August - early September.
- The number of bowhead whales migrating via offshore waters is not known.

G:RS - Sub-adult ringed seals summer in the offshore waters.

G:PB - Polar bears retreat northwards in association with the pack ice, as the summer progresses.

- Relatively small numbers remain along the coast during the open-water period.

ICE-COVERED PERIOD:

G:RS
- Ringed seals (adolescents and adults) are abundant in this zone surrounding the floe edge due to the abundance of leads (open or refrozen) which are used for breathing holes. Used from mid-October to mid-May.

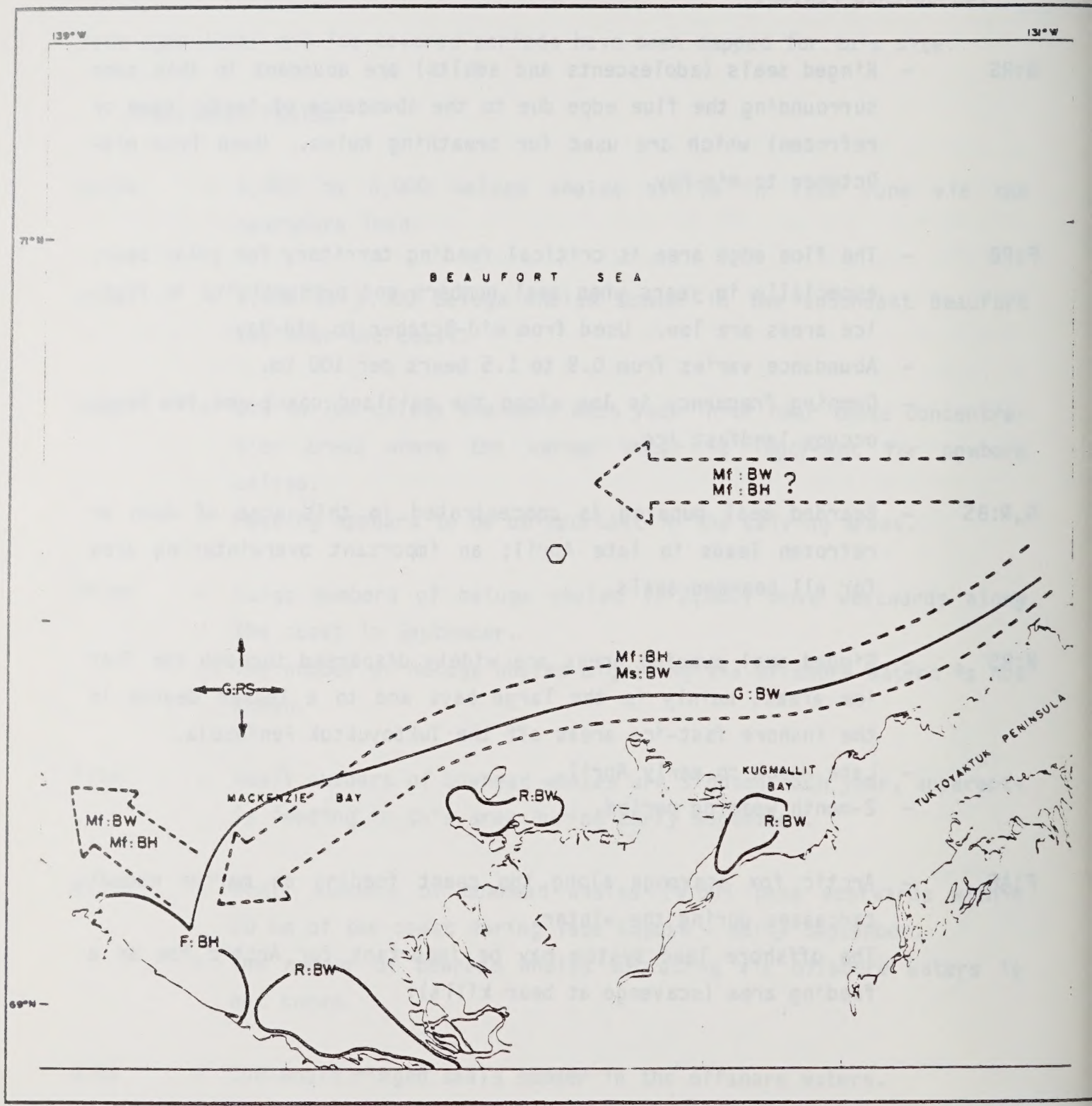
F:PB
- The floe edge area is critical feeding territory for polar bear, especially in years when seal numbers and productivity in fast-ice areas are low. Used from mid-October to mid-May.
- Abundance varies from 0.9 to 1.5 bears per 100 km.
- Denning frequency is low along the mainland coast and few bears occupy landfast ice.

G,R:BS
- Bearded seal pupping is concentrated in this area of open or refrozen leads in late April; an important overwintering area for all bearded seals.

R:RS
- Ringed seal pupping areas are widely dispersed through the fast ice areas, mainly in the large bays and to a lesser degree in the inshore fast-ice areas off the Tuktoyuktuk Peninsula.
- Late March to early April.
- 2-month weaning period.

F:AF
- Arctic fox scavenge along the coast feeding on marine mammal carcasses during the winter.
- The offshore lead system may be important for Arctic fox as a feeding area (scavenge at bear kills).

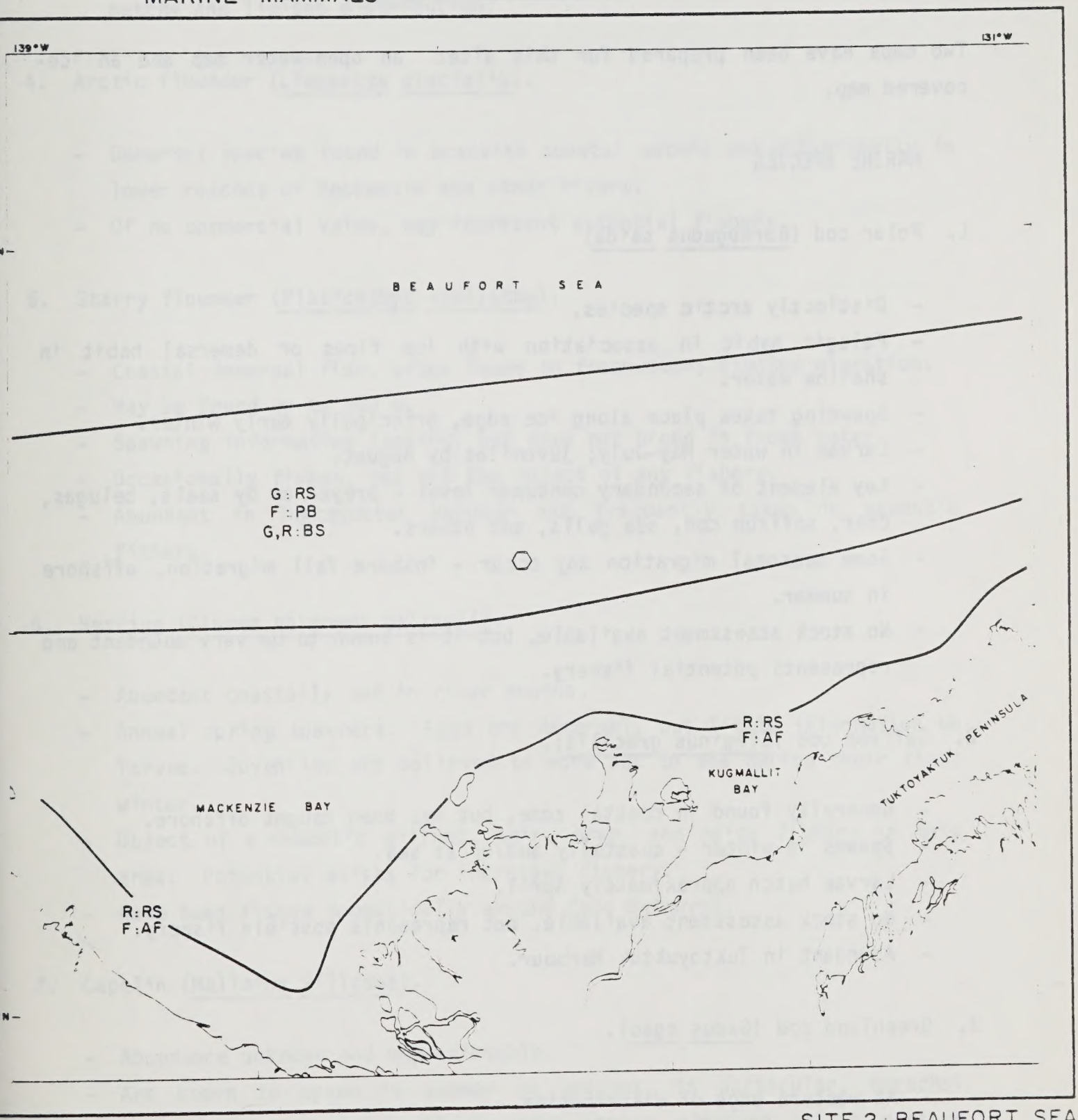
MARINE MAMMALS



SITE 2 : BEAUFORT SE
OPEN - WATER PERIOD

FIG. B.14

MARINE MAMMALS



SITE 2: BEAUFORT SEA
ICE-COVERED PERIOD

FIG. B.15

FISHERY RESOURCES

SITE 2: BEAUFORT SEA

Two maps have been prepared for this site: an open-water map and an ice-covered map.

MARINE SPECIES

1. Polar cod (Boreogadus saida)

   - Distinctly arctic species.
   - Pelagic habit in association with ice floes or demersal habit in shallow water.
   - Spawning takes place along ice edge, principally early winter.
   - Larvae in water May-July; juveniles by August.
   - Key element of secondary consumer level - preyed on by seals, belugas, char, saffron cod, sea gulls, and others.
   - Some seasonal migration may occur - inshore fall migration, offshore in summer.
   - No stock assessment available, but it is known to be very abundant and represents potential fishery.

2. Saffron cod (Eleginus gracilis).

   - Generally found in coastal zone, but has been caught offshore.
   - Spawns in winter - coastally and/or at sea.
   - Larvae hatch approximately April.
   - No stock assessment available, but represents possible fishery.
   - Abundant in Tuktoyuktuk Harbour.

3. Greenland cod (Gadus ogac).

   - At western edge of distribution.
   - Found in inlets and bays, rarely offshore.

- Abundance is small, except possibly for a large concentration in Coronation Gulf.
- Of no commercial importance. Future importance questionable due to patchy and limited distribution.

4. Arctic flounder (Liopsetta glacialis).

- Demersal species found in brackish coastal waters and occasionally in lower reaches of Mackenzie and other rivers.
- Of no commercial value, may represent potential fishery.

5. Starry flounder (Platichthys stellatus).

- Coastal demersal fish, often found in freshwater; limited migration.
- May be found up to 300 m.
- Spawning information lacking, but does not breed in fresh water.
- Occasionally fished, but not the object of any fishery.
- Abundant in Tuktoyuktuk Harbour and frequently taken in domestic fishery.

6. Herring (Clupea harengus pallasii).

- Abundant coastally and in river mouths.
- Annual spring spawners. Eggs are demersal, but little information on larvae. Juveniles are believed to move out to sea during their first winter.
- Object of a domestic gillnet, weir, trap, and seine fishery in this area. Potential exists for increased fishery.
- Have been fished domestically around Cape Bathurst.

7. Capelin (Mallotus villosus).

- Abundance unknown and unpredictable.
- Are known to spawn in summer on beaches, in particular, Herschel Island, but not known if spawning occurs offshore as in eastern Canada.

- Taken in seines when abundant.
- Represents potential fishery if stocks warrant.

8. Fourhorn sculpin (Myoxocephalus quadricornis).

- Abundant demersal fish.
- No commercial value.
- Has freshwater and marine populations.
- Plentiful along Tuktoyuktuk Peninsula.

ANADROMOUS SPECIES

1. Whitefish (Coregonidae)

- Five major species found in this area:
  - Coregonus nasus (broad whitefish)
  - C. autumnalis (arctic cisco)
  - C. sardinella (least cisco)
  - C. Clupeaformis (lake whitefish)
  - Stenodus leucichthys (inconnu)

- All species exhibit upstream spawning runs in spring and summer.
- Migrate downstream after spawning but usually before freeze-up.
- Information on juveniles limited.
- Fry generally move downstream after one or two years.
- Important food source for larger fish, particularly lake trout, pike, burbot, and other whitefish.
- Was important to commercial fisheries in the area, especially broad and lake whitefish and inconnu. Broad whitefish comprised up to 72% of total catches. Also important as a sportfishery. Used now for domestic purposes, especially arctic cisco.
- Fished by gillnets during fall and/or spring runs. Lake whitefish also the object of a winter fishery and arctic cisco and broad whitefish often taken in a summer fishery.

- Prosopium cylindroceum (round whitefish) also found in this area, but in reduced numbers. Exhibits fall spawning migration.
- Cisco/whitefish hybrids have been found on Tuktoyuktuk Peninsula.

2. Smelt (Osmerus mordax)

- Pelagic marine species which migrates upstream during spring (often before break-up).
- Important as a food source for lake trout, burbot, smelt and sea gulls.
- Plentiful in this area.
- Abundant in Kugmallit Bay.

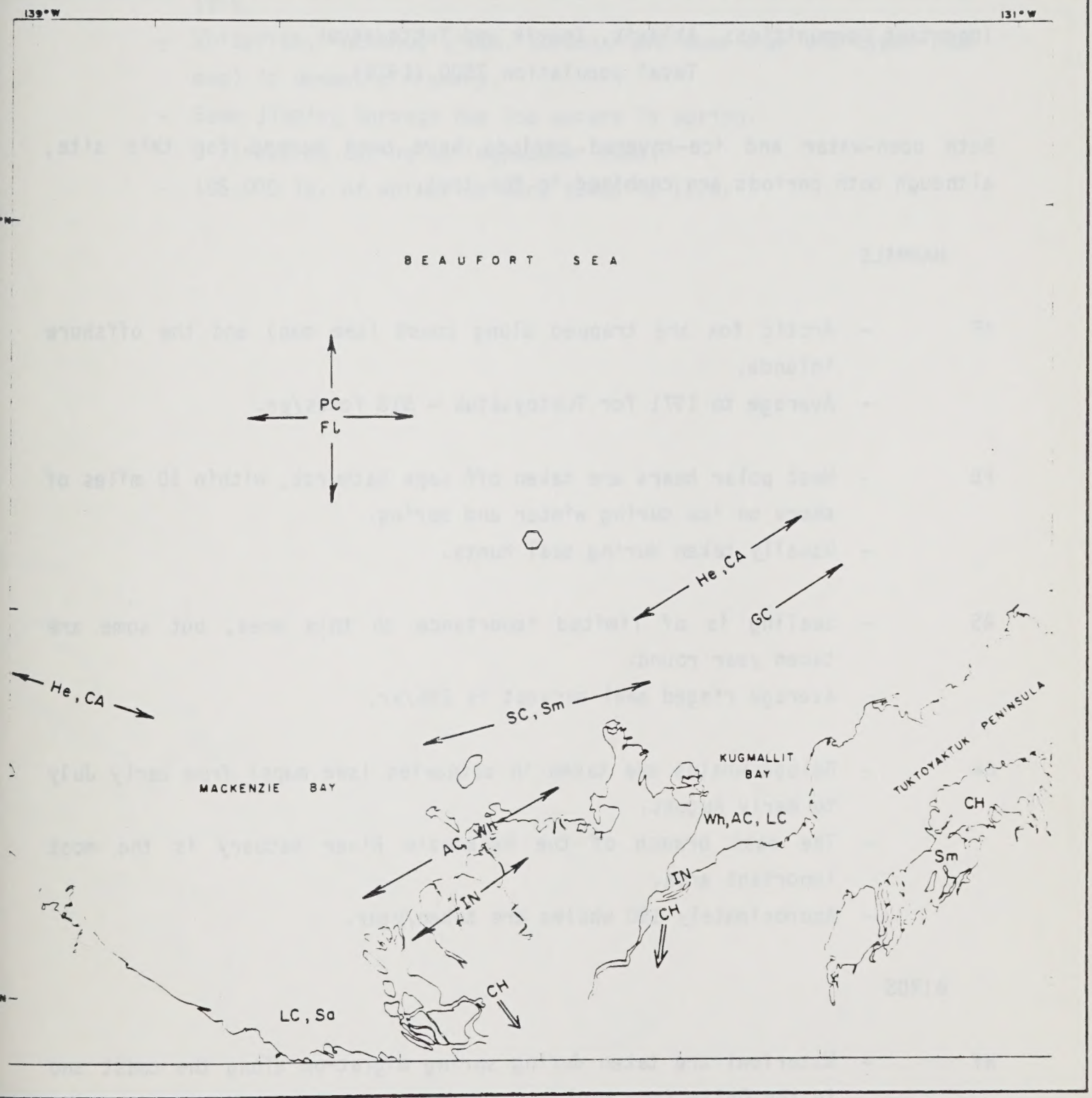
3. Arctic char (Salvelinus alpinus)

- Runs to sea in spring to feed.
- Returns to rivers and streams in late summer/fall to spawn.
- Slow growing fish.
- Eggs incubate overwinter; smolts remain in rivers and lakes for 5-7 years before running to sea (150-200 mm length).
- Fished domestically by gillnets, traps and spears during summer and the fall run. May also be fished in sea surrounding southern Banks Island.
- Important also for sportfishing.
- Important food source for man, terns, loons, char and seals.

FISHERY RESOURCES

SITE 2: BEAUFORT SE
OPEN-WATER PERIOD

FIG. B.16



SITE 2 : BEAUFORT SEA
ICE-COVERED PERIOD

FIG. B.17

SITE 2: BEAUFORT SEA

Important Communities: Aklavik, Inuvik and Tuktoyaktuk
Total population 7500 (1978)

Both open-water and ice-covered periods have been mapped for this site, although both periods are combined in the text.

MAMMALS

AF
- Arctic fox are trapped along coast (see map) and the offshore inlands.
- Average to 1971 for Tuktoyaktuk - 518 foxes/yr.

PB
- Most polar bears are taken off Cape Bathurst, within 10 miles of shore on ice during winter and spring.
- Usually taken during seal hunts.

RS
- Sealing is of limited importance to this area, but some are taken year round.
- Average ringed seal harvest is 286/yr.

BW
- Beluga whales are taken in estuaries (see maps) from early July to early August.
- The east branch of the Mackenzie River estuary is the most important area.
- Approximately 150 whales are taken/year.

BIRDS

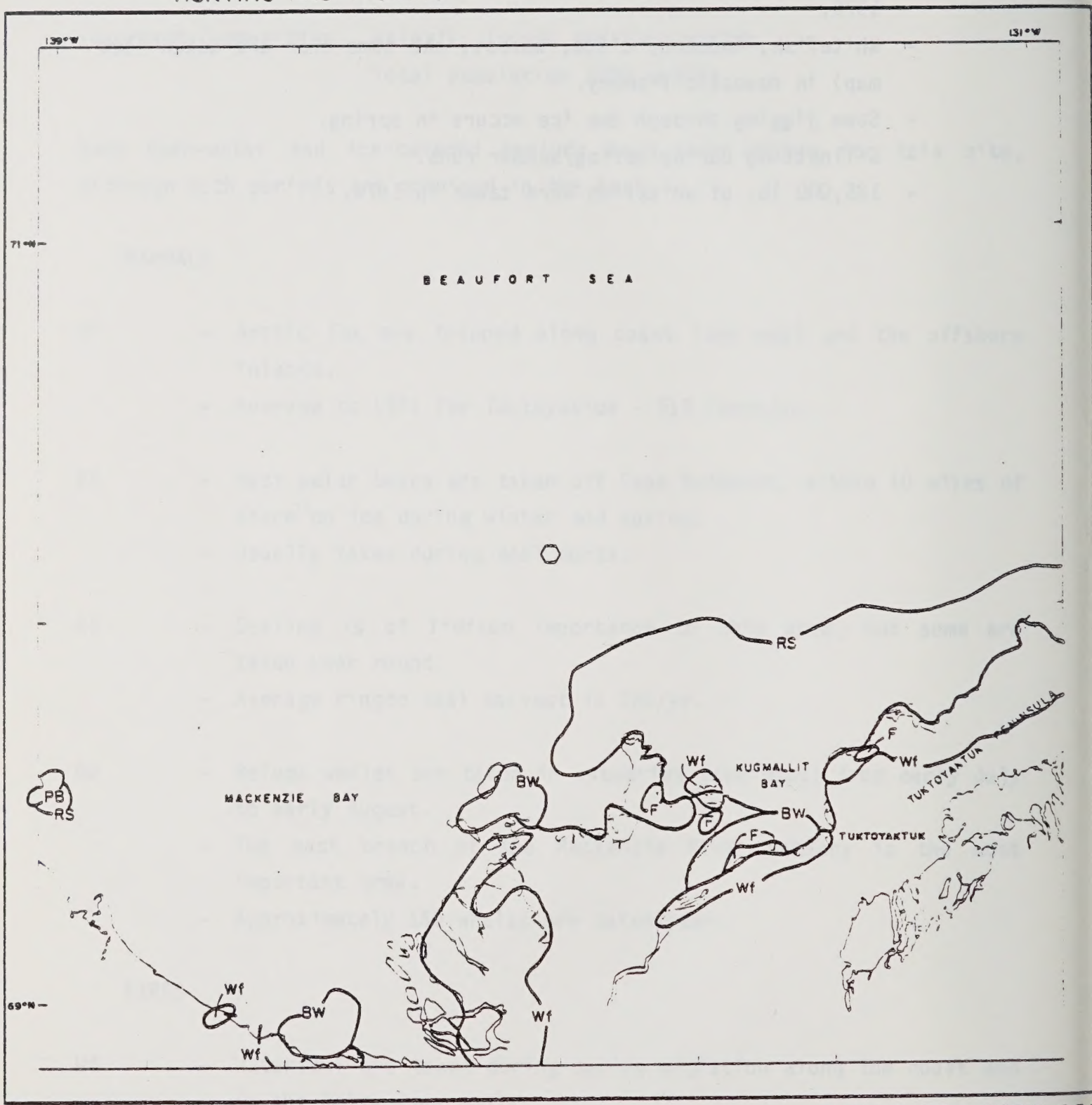
Wf
- Waterfowl are taken during spring migration along the coast and in the Delta (see map).

FISHERIES

Ff

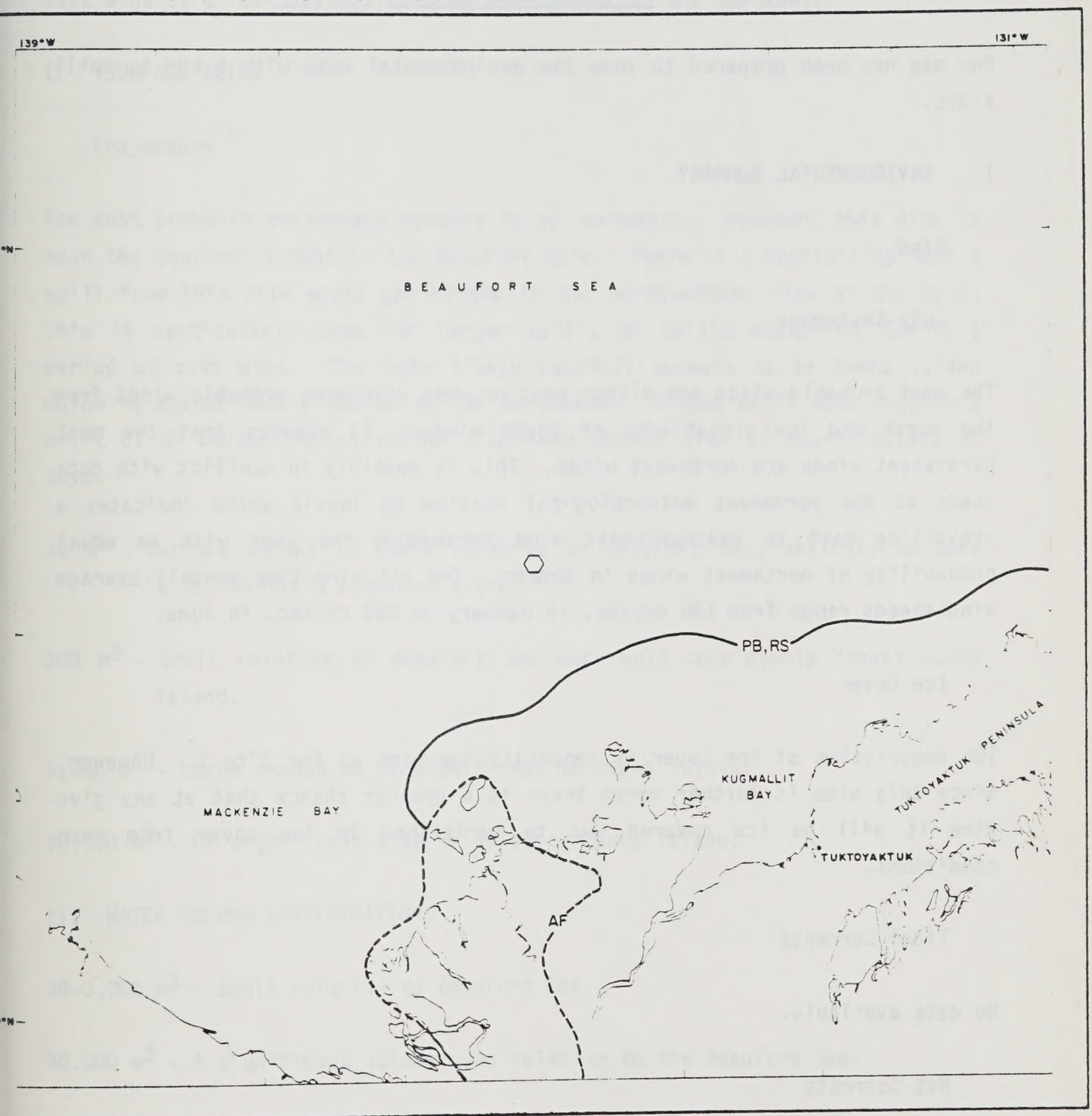
- Commercial ciscoe and whitefish fishery has been closed since 1979.
- Whitefish, inconnu, cisco, burbot, and some char are taken (see map) in domestic fishery.
- Some jigging through the ice occurs in spring.
- Gillnetting during spring/summer runs.
- 185,000 lb. of whitefish were taken in 1974.

HUNTING AND FISHING



SITE 2: BEAUFORT SEA
OPEN-WATER PERIOD

FIG. B.18



SITE 2 : BEAUFORT SEA
ICE-COVERED PERIOD

FIG. B.19

HYPOTHETICAL SLICK MOVEMENT

SITE 2: BEAUFORT SEA

One map has been prepared to show the environmental data with a key to spill sizes.

I ENVIRONMENTAL SUMMARY

Wind

July-September

The most probable winds are either east or west with more probable winds from the north and low probability of south winds. It appears that the most persistent winds are northwest winds. This is possibly in conflict with data taken at the permanent meteorological station at Inuvik which indicates a prevailing east to eastnortheast wind throughout the year with an equal probability of northwest winds in summer. The all direction monthly average wind speeds range from 190 cm/sec. in January to 360 cm/sec. in June.

Ice Cover

The description of ice cover is generally the same as for Site 1. However, since this site is further north there is a greater chance that at any give time it will be ice covered due to variations in ice cover from mean conditions.

Tidal Currents

No data available.

Net Currents

The currents in the Beaufort Sea south of the Beaufort Gyre are affected by many factors whose interactions are poorly understood. The most prominent

factors are the fresh water inflow of the Mackenzie River and the wind. The predominant current in the southern Beaufort Sea is northeast. However an east wind of a few days may reverse the current to the northwest.

II SURFACE SLICK

Trajectory

The most probable trajectory appears to be northeast. However, this site is near the southern extent of the Beaufort Gyre. There is a possibility that a spill from this site would get caught in the northwestern flow of the Gyre. This is particularly true for larger spills or spills occurring during a period of east wind. The only likely landfall appears to be Banks Island which is approximately 400 km to the northeast. Drogue drift data suggest a drift of 40 cm/sec. which yeilds a minimum travel time of approximately 12 days.

30 m^3 - Surface extent is small relative to Beaufort Sea; unlikely to make it to land as a coherent slick.

300 m^3 - Small relative to Beaufort Sea but could concievably impact Banks Island.

3,000 m^3 - Large enough to be significant to Banks Island.

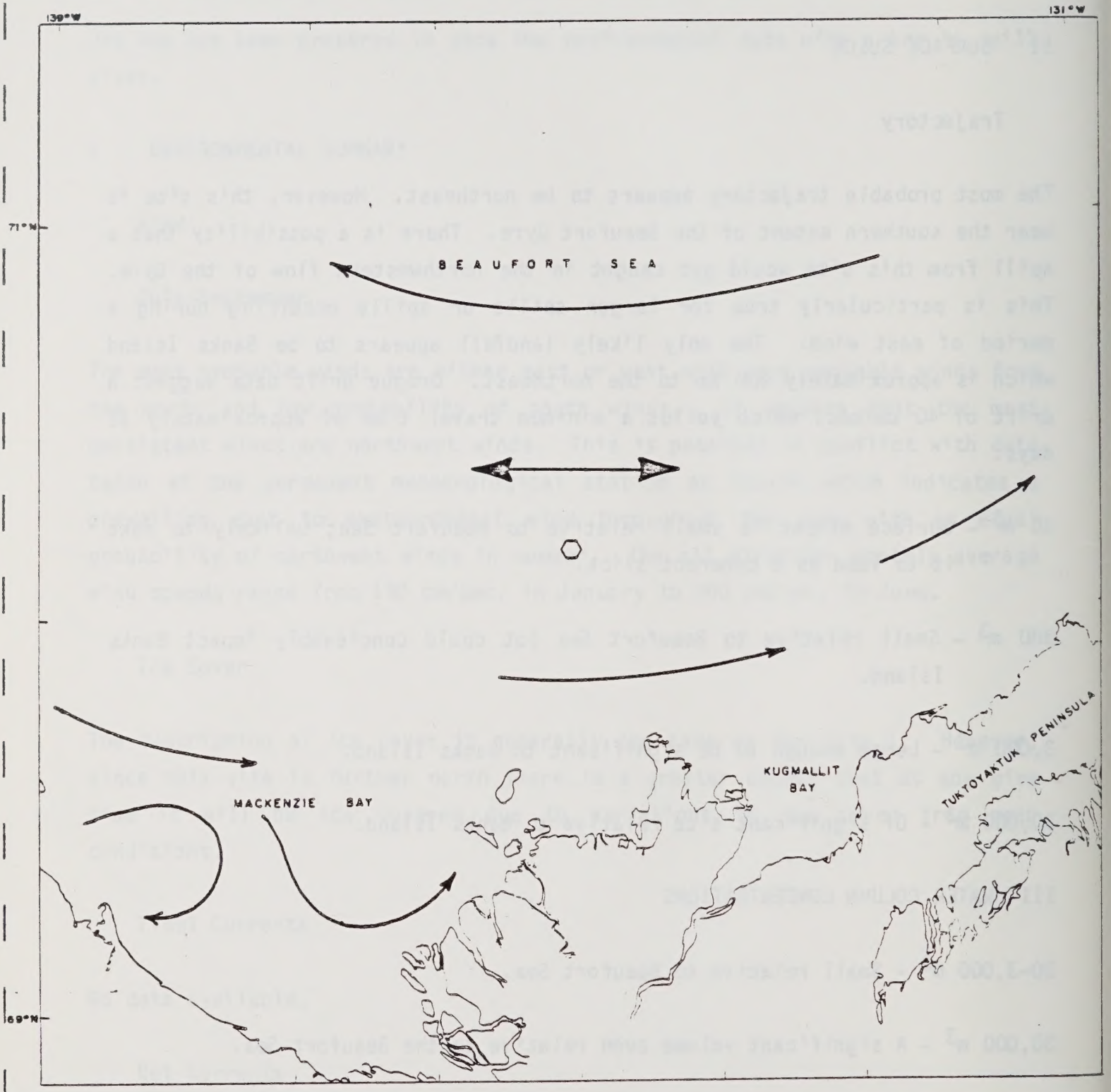
30,000 m^3 - Of significant size relative to Banks Island.

III WATER COLUMN CONCENTRATIONS

30-3,000 m^3 - Small relative to Beaufort Sea.

30,000 m^3 - A significant volume even relative to the Beaufort Sea.

HYPOTHETICAL SLICK MOVEMENT



SITE 2 : BEAUFORT SE

Spill Volume	Slick Diameter	Diameter 100 ppb Contamination
30 m^3	1.8 km	4.1 km
300 m^3	5.6 km	13.0 km
3000 m^3	18 km	41 km
30000 m^3	45 km	130 km

FIG. B.20

SITE 3: ARMSTRONG POINT

No maps have been prepared for this site since there are very few data available.

Pl
- Break-up of ice in Prince of Wales Strait begins in July; clears to south into Amundsen Gulf.
- Open-water in south half of Strait by August.
- Ice 4/10 - 6/10 throughout Strait in September.

Pp
- No data available.
- Epontic peak probably late May/early June.
- Phytoplankton productivity probably low.

Zp
- No data.

Zb
- No data.
- Substrate unknown/depth generally less than 100 m.

SEABIRDS

SITE 3: ARMSTRONG POINT

Only the open-water period has been mapped; little activity occurs during the ice-covered period.

N:WfSh

- Banks Island Migratory Bird Sanctuary #1. One of the major lesser snow goose nesting areas (up to 200,000 geese) in the western Arctic. An estimated 150,000 king eiders, and 9,000 brant also nest. Other species include common eiders, loons, sandhill cranes, and shorebirds which nest along lakes and rivers May 15 - September 15.

Mo:SNBB

- Banks Island Migratory Bird Sanctuary #2. Thomsen River; major moulting area for snow geese and black brant; July 1 - August 15.

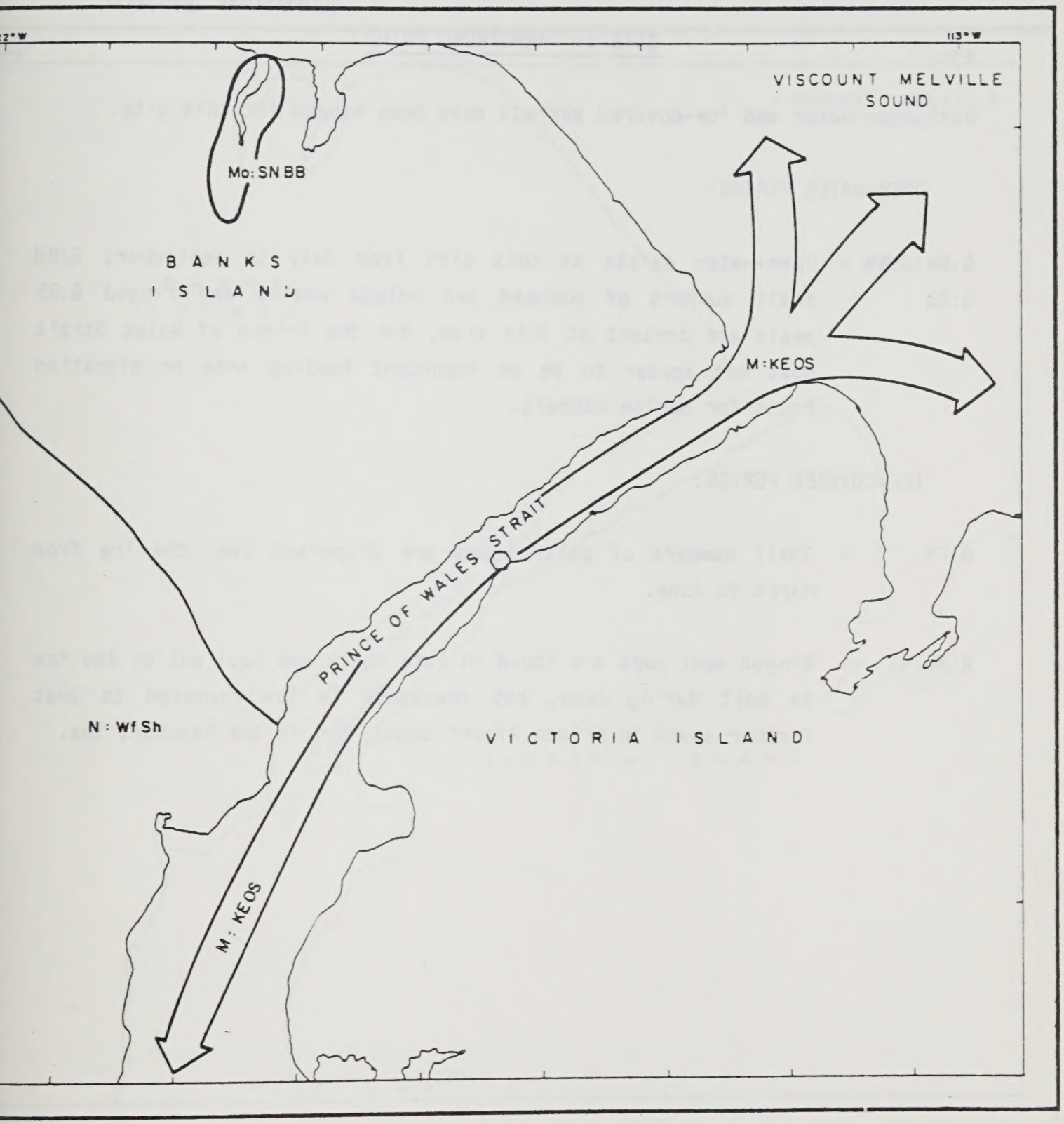
M:KEOS

- Prince of Wales Strait. Spring and fall migration route king eiders and oldsquaws.

GENERAL

Very large numbers of seabirds and waterfowl occur in the marine environment from early spring to September (not rigid dates). Banks Island has large population of shore-birds (e.g., 35,000 Ruddy Turnstones). Comprehensive data on shoreline use is lacking.

SEABIRDS



SITE 3 : ARMSTRONG POINT
OPEN - WATER PERIOD

FIG. B. 21

SITE 3: ARMSTRONG POINT

Both open-water and ice-covered periods have been mapped for this site.

OPEN-WATER PERIOD:

G:BW:G:BH G:RS - Open-water exists at this site from July to September; small numbers of bowhead and beluga whales and ringed seals are present at this time, but the Prince of Wales Strait does not appear to be an important feeding area or migration route for marine mammals.

ICE-COVERED PERIOD:

G:PB - Small numbers of polar bears are dispersed over the ice from March to June.

R,Mo:RS - Ringed seal pups are found in late March and haul out on the ice to molt during June, but abundance is low compared to that further south in Prince Albert Sound, and in the Beaufort Sea.

MARINE MAMMALS

SITE 3 : ARMSTRONG POINT
OPEN-WATER PERIOD

FIG. B.22

SITE 3 : ARMSTRONG POINT
ICE-COVERED PERIOD

FIG. B.23

SITE 3: ARMSTRONG POINT

Open-water and ice-covered periods have been combined in one map for this site.

MARINE SPECIES

1. Polar Cod (Boreogadus saida)

- Distinctly arctic species.
- Pelagic habit in association with ice floes or demersal habit in shallow water.
- Spawning takes place along ice edge, principally early winter.
- Larvae in water May-July; juveniles by August.
- Key element of secondary consumer level, preyed on by seals, belugas, char, sea gulls, and other birds and fish.
- Some seasonal migration may occur - inshore fall migration, offshore in summer.
- No stock assessment available, but it is known to be very abundant and represents potential fishery

2. Whitefish (Coregonidae)

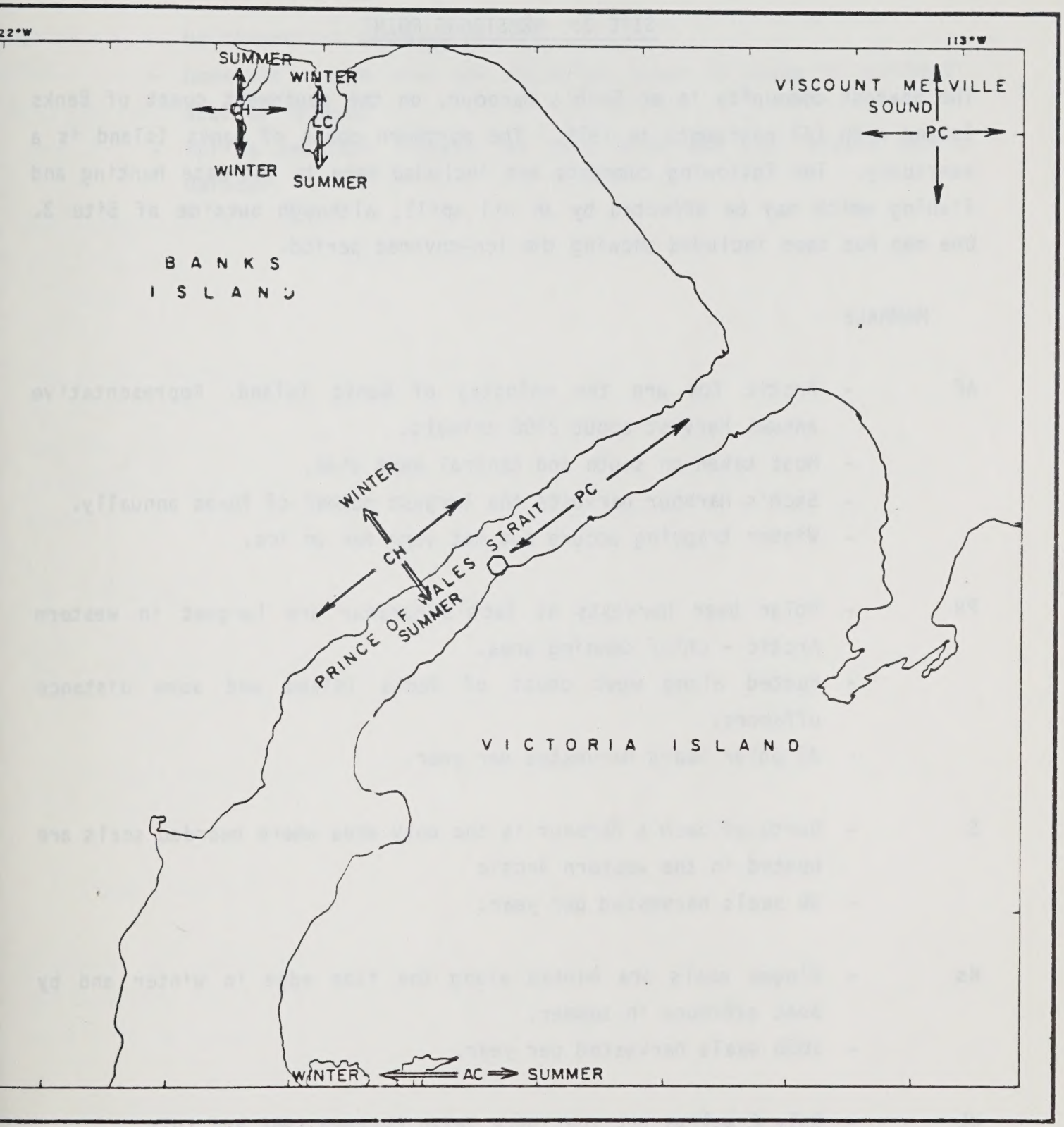
- Two major species found in this area:
  - C. autumnalis (arctic cisco)
  - C. sardinella (least cisco)

- Both species exhibit upstream spawning runs in spring and summer.
- Migrate downstream after spawning but usually before freeze-up.
- Information on juveniles limited.
- Fry generally move downstream after one or two years.
- Some domestic fishing done in lakes.

3. Arctic Char (Salvelinus alpinus)

- Runs to sea in spring to feed.
- Returns to rivers and streams in late summer/fall to spawn.
- Slow growing fish.
- Eggs incubate overwinter; smolts remain in rivers and lakes for 5-7 years before running to sea (150-200 mm length).
- Fished domestically by gillnets, traps and spears during summer and the fall run.
- Important food source for man, terns, loons, char and seals.

FISHERY RESOURCES



SITE 3 : ARMSTRONG POINT

FIG. B.24

SITE 3: ARMSTRONG POINT

The nearest community is at Sach's Harbour, on the southwest coast of Banks Island with 167 residents in 1978. The northern coast of Banks Island is a sanctuary. The following comments are included here to indicate hunting and fishing which may be affected by an oil spill, although outside of Site 3. One map has been included showing the ice-covered period.

MAMMALS

AF
- Arctic fox are the mainstay of Banks Island. Representative annual harvest about 2700 animals.
- Most taken on south and central east side.
- Sach's Harbour harvests the largest number of foxes annually.
- Winter trapping occurs but not very far on ice.

PB
- Polar bear harvests at Sach's Harbour are largest in western Arctic - chief denning area.
- Hunted along west coast of Banks Island and some distance offshore.
- 23 polar bears harvested per year.

S
- North of Sach's Harbour is the only area where bearded seals are hunted in the western Arctic
- 50 seals harvested per year.

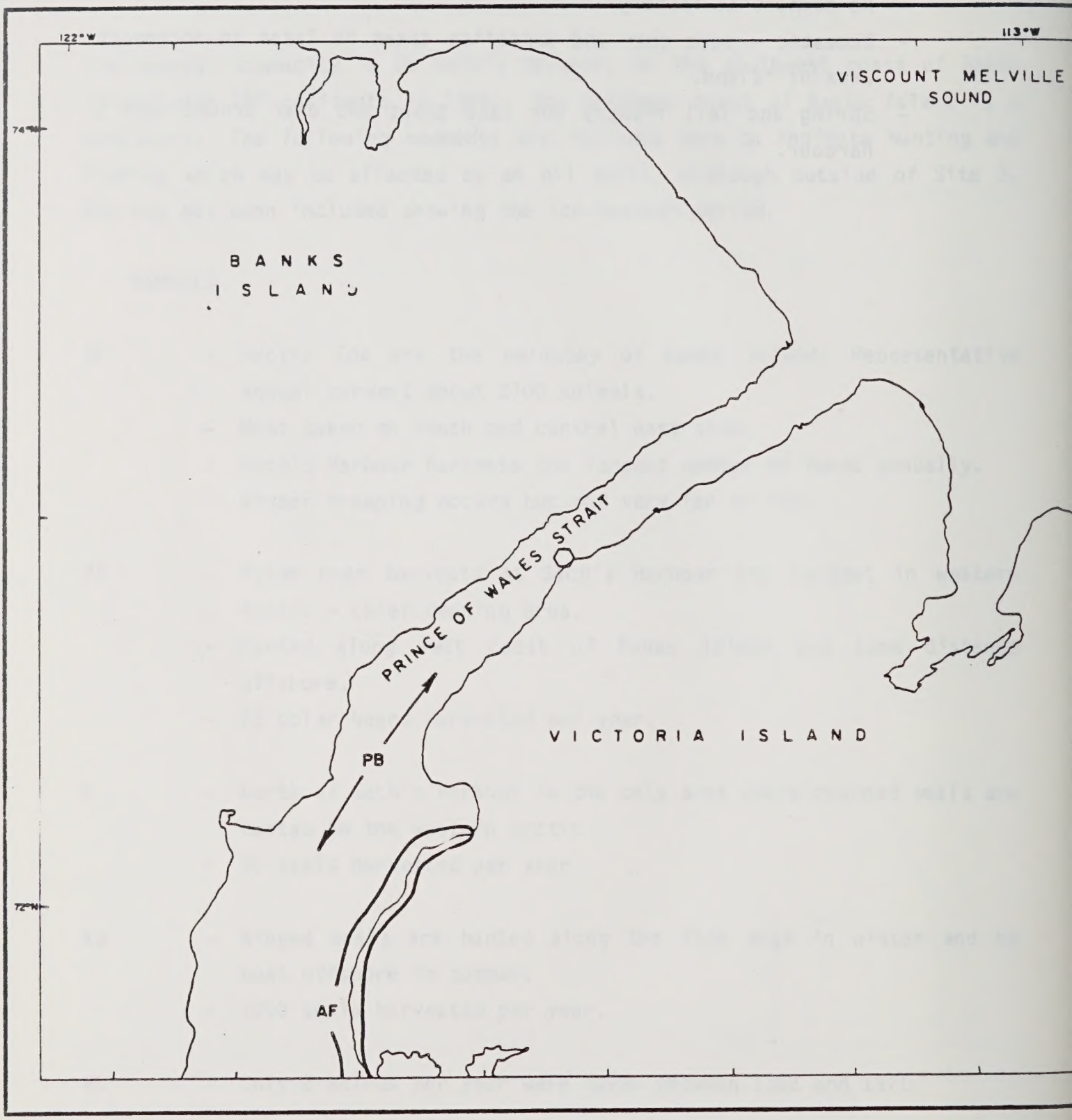
Rs
- Ringed seals are hunted along the floe edge in winter and by boat offshore in summer.
- 1000 seals harvested per year.

WL
- Only 2 walrus per year were taken between 1962 and 1971.

FISHERIES

F
- No commercial fishery.
- Domestic - some char and whitefish taken in lakes in northeast area of island.
- Spring and fall fishery for lake trout and char around Sach's Harbour.

HUNTING AND FISHING



SITE 3 : ARMSTRONG PO
ICE - COVERED PERIOD

HYPOTHETICAL SLICK MOVEMENT

SITE 3: ARMSTRONG POINT

One map has been prepared to show the environmental data with a key to spill sizes.

I ENVIRONMENTAL SUMMARY

Wind

The nearest permanent meteorological station reported in the Canadian Normals is Sach's Harbour on Banks Island, which reports monthly winds between 490 and 590 cm/sec. The most probable wind direction throughout the year is southeast. The probability is relatively evenly distributed from northeast clockwise to south with low probability of winds from south to northwest.

Ice Cover

- The maximum coverage for August is 7-9+/10 in the northeastern half of Prince of Wales Strait; open water in the southwestern half of Strait.
- The minimum coverage for September is 4-6/10 through the entire strait.

Tidal Currents

Currents of approximately 25 cm/sec have been measured under ice in the northeastern end of the Strait. Measurements in the southwestern end of the strait in September indicate currents of 77 cm/sec.

Net Currents

Under ice tidal current measurements resulted in a net current of approximately 2 cm/sec at 250°T. The pilot of Arctic Canada reports a dual

would probably move on and offshore with the wind covering one or both shorelines with oil. It is reasonable to assume that it might cover the channel surface for weeks or months.

III WATER COLUMN CONCENTRATIONS

General

The assumption that the surface slick stays over the dispersed oil becomes more valid in confined areas for larger volume spills. As the area affected by the dispersed oil reaches across the channel, the problem would be more closely approximated by a 1-dimensional treatment with the oily water treated as horizontally uniform with dispersion occurring only at the ends.

30 m^3 - The affected area is small in scale and might only be of significance if the spill occurred during a biologically sensitive period.

300 m^3 - The area of contamination is approaching the width of the Strait.

3,000 m^3 - The width of the Strait could be totally affected as well as a substantial distance down-current.

30,000 m^3 - For a spill of this size in the Strait, the worst case assumption may be quite realistic. The surface slick and the dispersed oil would probably stay in close proximity, allowing for continued dispersion into the same water mass. Data gathered under ice indicte a thermocline at approximtely 15 m. Using this depth with the 45% entrainment yields a length of affected channel 600 km long. Alternately, using a depth profile (from Peck, 1977) across the channel and mixing the oil to the bottom (30-90 m) results in an affected length of 140 km. Both of these calculations lead to the projections that oil concentrations in the lethal range (> 100 ppb) could occur in much or all of the Strait.

SITE 4: VISCOUNT MELVILLE SOUND

Only the open-water period has been mapped; little information is available for the ice-covered period.

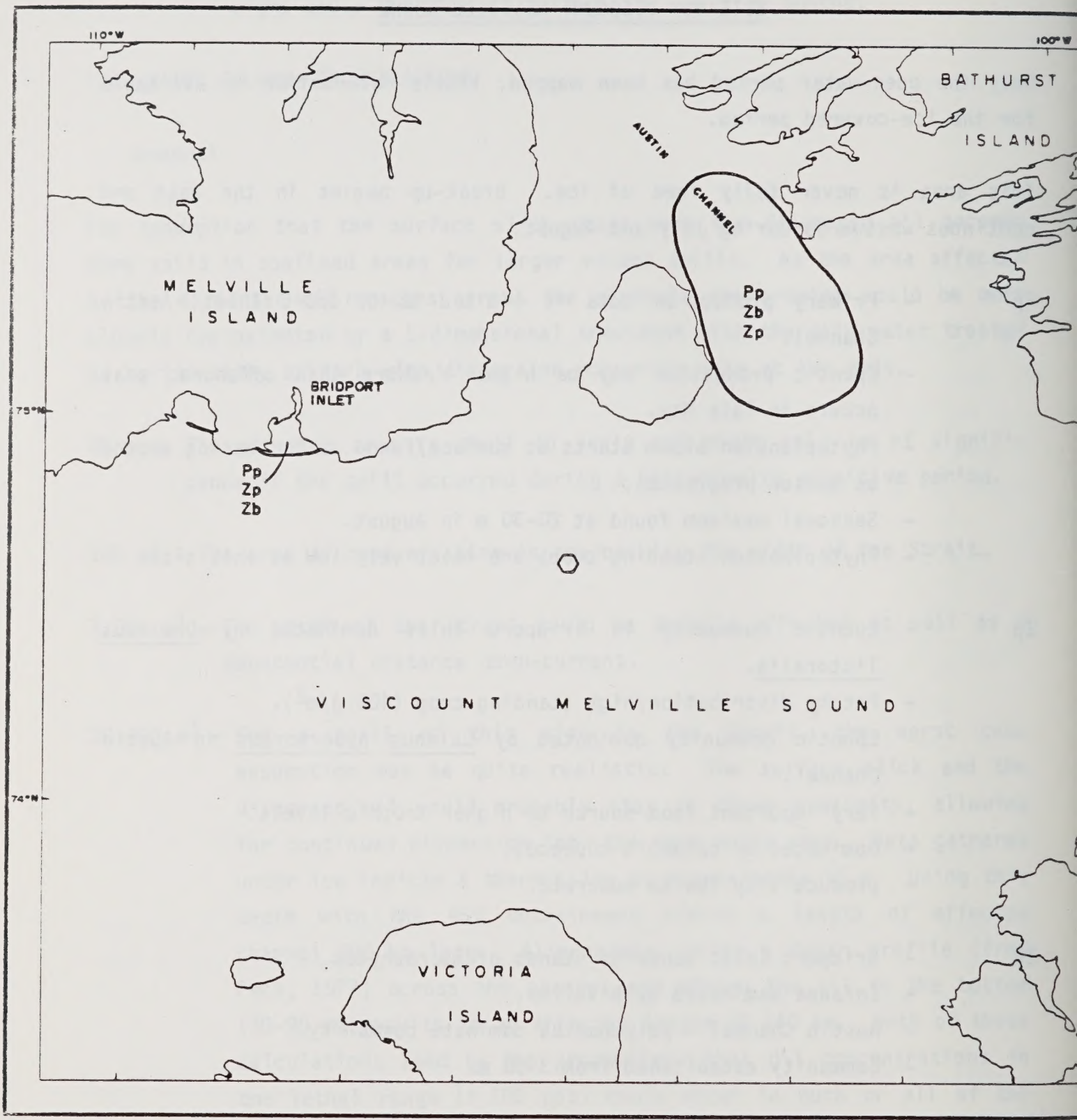
This area is never fully free of ice. Break-up begins in the east and continues westwards during July and August.

Pp
- Primary production data is limited to Bridport Inlet, Austin Channel.
- Epontic production may be higher inshore than offshore; peak occurs in late May.
- Phytoplankton bloom starts at surface/found at increasing depths as season progresses.
- Seasonal maximum found at 20-30 m in August.
- Phytoplankton standing crops are relatively low at this site.

Zp
- Epontic community in Bridport Inlet dominated by Onesimus littoralis.
- Patchy distribution/high standing crop (400 g/m^2).
- Epontic community dominated by Calanus hyperboreus in Austin Channel.
- Very important food source to higher trophic levels.
- Dominated by calanoid copepods.
- productivity low to moderate.

Zb
- Bridport Inlet contains stands of macrophytes.
- Infauna dominated by bivalves.
- Austin Channel - polychaetes dominate community.
- Community established from 3-50 m.

PLANKTON / INVERTEBRATES



SITE 4 : VISCOUNT MELVILLE SOU
OPEN - WATER PERIOD

FIG B

SEABIRDS

SITE 4: VISCOUNT MELVILLE SOUND

Only the open-water period has been mapped; activity during the ice- covered period is limited.

OPEN-WATER PERIOD

NMoS:Br

- Northeastern Melville Island. Brant breeding, moulting and staging area.

NMo:Br

- Bridport Inlet - Melville Island. Nesting and moulting brant.

Mo:Br

- Skene Bay - Melville Island. Moulting brant.

N:Wf(1)

- King Point - Melville Island. Upland breeding area for waterfowl.

EdGuShF

- King Point - Melville Island. Coastal and offshore used by eiders, gulls and shorebirds.

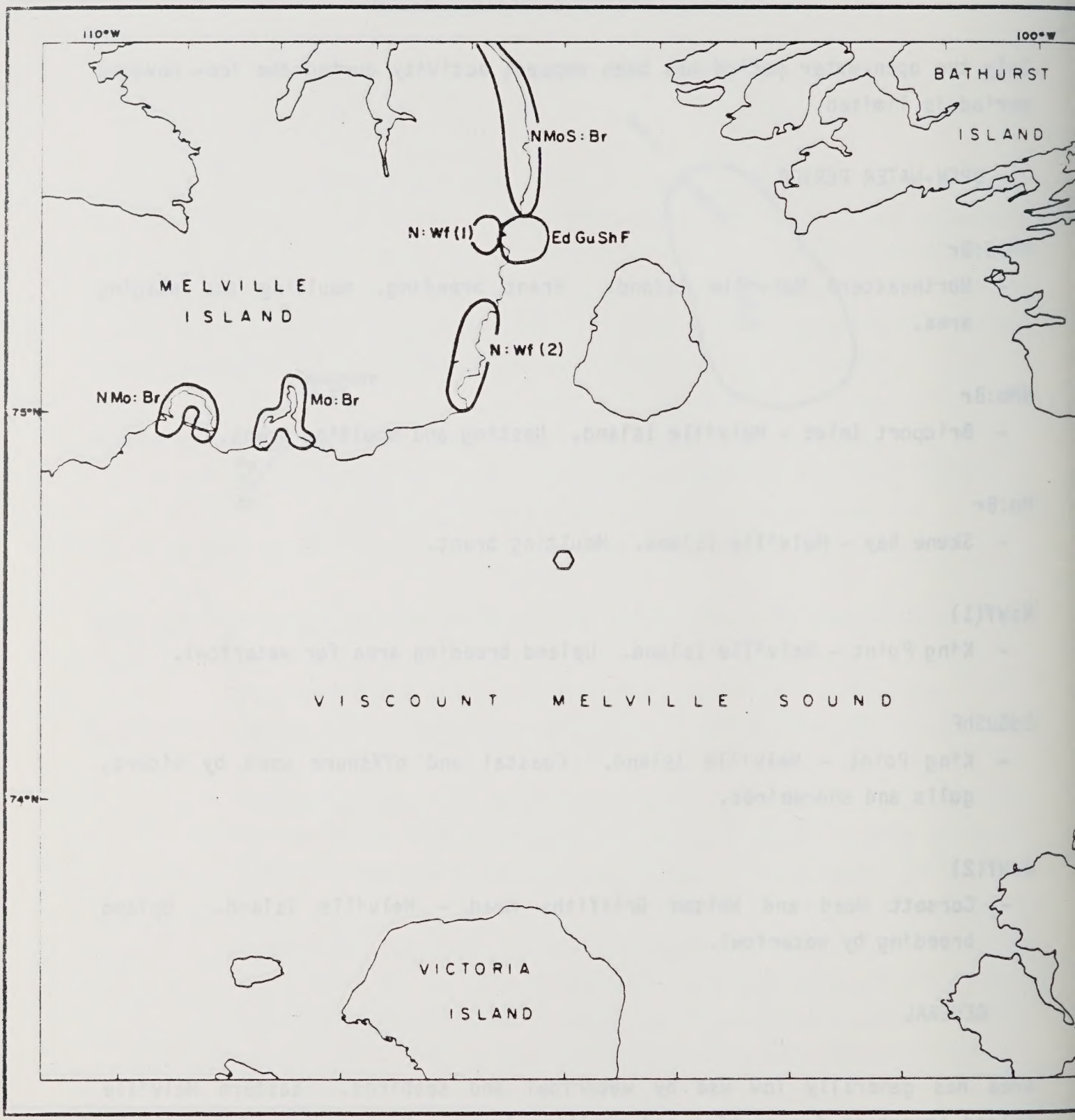
N:Wf(2)

- Corsett Head and Nelson Griffiths Head - Melville Island. Upland breeding by waterfowl.

GENERAL

Area has generally low use by waterfowl and seabirds. Eastern Melville Island important for nesting and moulting brant. Numbers vary from year to year between 1200 - 1500 individuals.

SEABIRDS



SITE 4 : VISCOUNT MELVILLE SO
OPEN- WATER PERIOD

FIG. B

SITE 4: VISCOUNT MELVILLE SOUND

Both open-water and ice-covered periods have been mapped for this site.

OPEN-WATER PERIOD: (August and September ≃ 5/10 Ice-Cover)

G:BS
- The density of bearded seals along the southeast coast of Melville Island is relatively high compared to other areas (0.09/km^2).
- Bearded seals are also present in Graham Moore Bay, and at southeast Byam Martin Island.
- Migration routes to and from summer feeding grounds are not yet known.

G:RS
- The northeast coast of Byam Martin Island supports a high density of ringed seals (≃ 2.5 seals/km^2).

F:PB
- Polar bears are present in low numbers along the Melville Island coast and many concentrate in large bays during the spring, before moving onto the land (e.g., Graham Moore Bay).

G:PB
- Polar bear densities are high off northeast Victoria Island where the ice cover remains solid all year.

ICE-COVERED PERIOD:

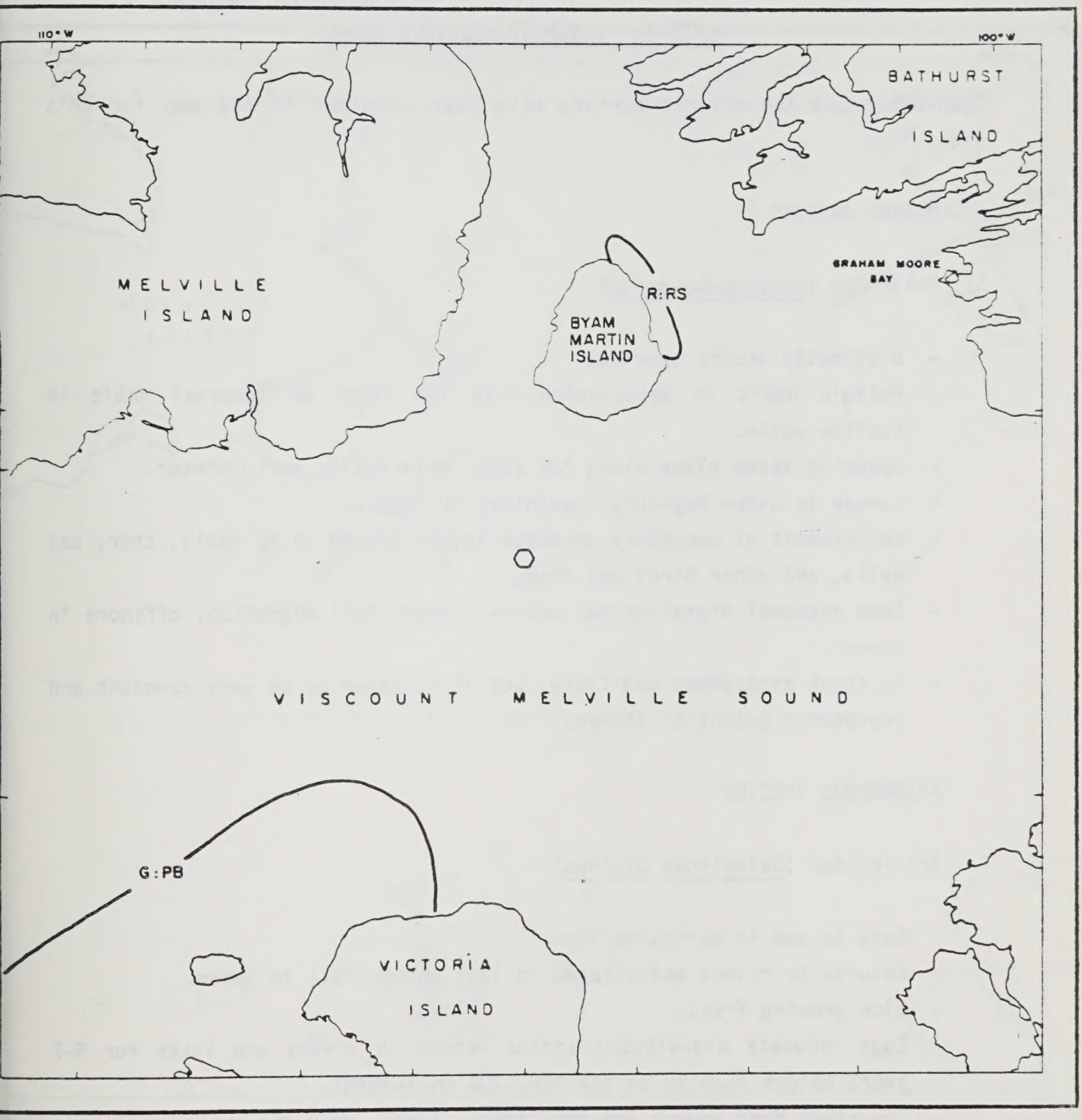
R:RS
- Ringed seal whelping occurs in late March and early April in lairs on the fast ice.

G:PB
- Polar bears are dispersed over the ice during the winter and tend to concentrate where the ice shifts during the winter to produce open water leads where seals may be more abundant and accessible.

MARINE MAMMALS

SITE 4 : VISCOUNT MELVILLE SOU
OPEN - WATER PERIOD

FIG B2



SITE 4 : VISCOUNT MELVILLE SOUND
ICE - COVERED PERIOD

SITE 4: VISCOUNT MELVILLE SOUND

Open-water and ice-covered periods have been combined in one map for this site.

MARINE SPECIES

1. Polar Cod (Boreogadus saida)

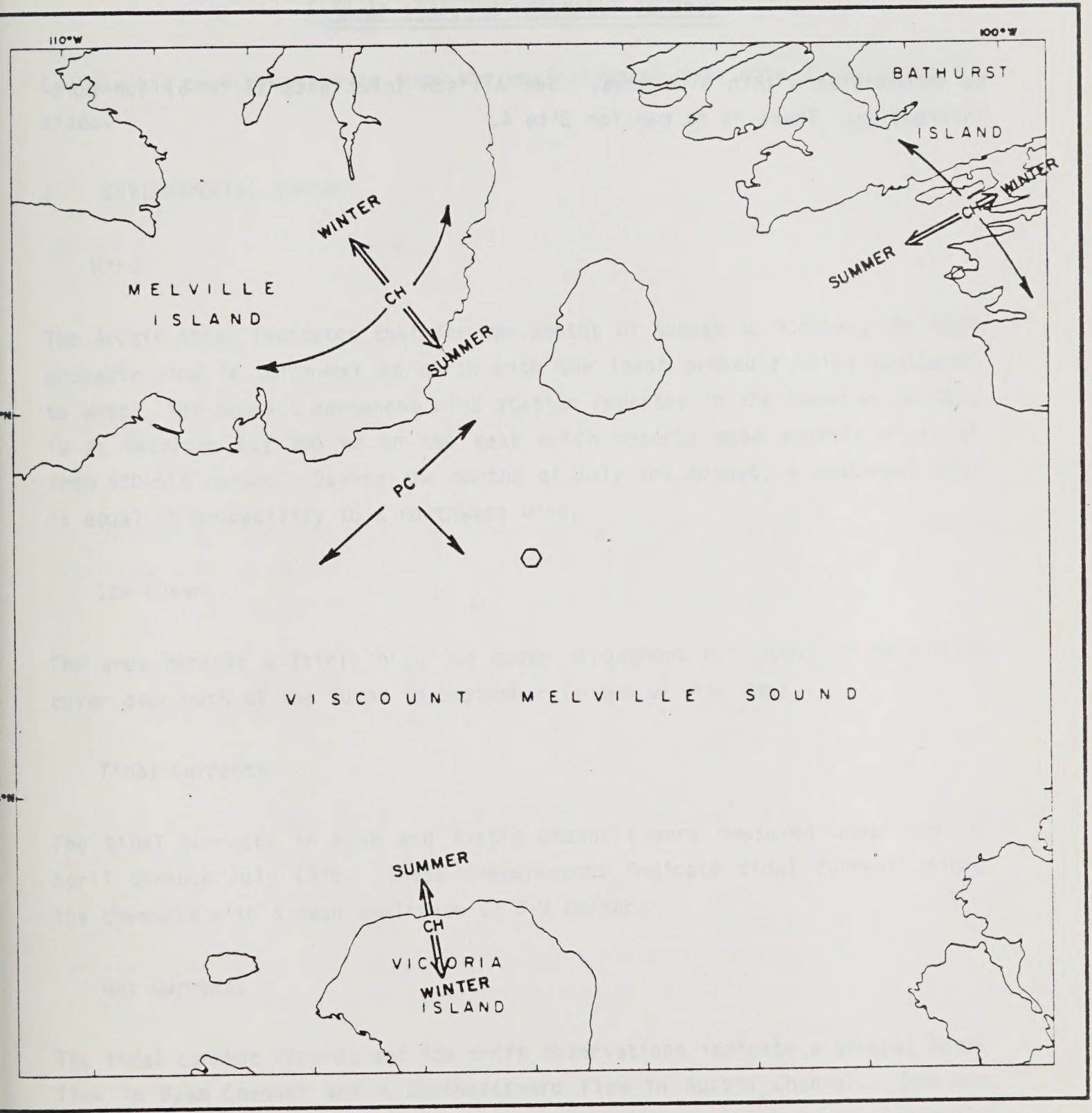
- Distinctly arctic species.
- Pelagic habit in association with ice floes or demersal habit in shallow water.
- Spawning takes place along ice edge, principally early winter.
- Larvae in water May-July; juveniles by August.
- Key element of secondary consumer level, preyed on by seals, char, sea gulls, and other birds and fish.
- Some seasonal migration may occur- inshore fall migration, offshore in summer.
- No stock assessment available, but it is known to be very abundant and represents potential fishery.

ANADROMOUS SPECIES

1. Arctic Char (Salvelinus alpinus)

- Runs to sea in spring to feed.
- Returns to rivers and streams in late summer/fall to spawn.
- Slow growing fish.
- Eggs incubate overwinter; smolts remain in rivers and lakes for 5-7 years before running to sea (150-200 mm length).
- Important food source for man, terns, loons, char and seals.

FISHERY RESOURCES



SITE 4 : VISCOUNT MELVILLE SOUND

FIG. B. 31

SITE 4: VISCOUNT MELVILLE SOUND

No communities within site area. See Allison Inlet data (Site 6) for more information. There is no map for Site 4.

HYPOTHETICAL SLICK MOVEMENT

SITE 4: VISCOUNT MELVILLE SOUND

One map has been prepared to show the environmental data with a key to spill sizes.

I ENVIRONMENTAL SUMMARY

Wind

The Arctic Atlas indicates that for the months of August to October, the most probable wind is northwest to north with the least probable being southeast to west. The nearest permanent wind station reported in the Canadian Normals is at Resolute Bay 300 km to the east which reports mean monthly winds of from 520-615 cm/sec. During the months of July and August, a southeast wind is equal in probability to a northwest wind.

Ice Cover

The area retains a fairly high ice cover throughout but opens up to 1-3/10 cover over much of the Sound in September (shown on site map).

Tidal Currents

The tidal currents in Byam and Austin Channels were measured under ice in April through July 1976. These measurements indicate tidal currents along the channels with a mean amplitude of 5-9 cm/sec.

Net Currents

The tidal current records and ice drift observations indicate a general South flow in Byam Channel and a Southeastward flow in Austin Channel. Ice and boat drift information in Viscount Melville Sound indicate a generally eastward flow (15 cm/sec.). This is verified by the pilot of Arctic Canada

which also notes exceptions. The surface current is probably quite sensitive to the wind.

II SURFACE SLICK

Trajectory

The most probable trajectory would be to the Southeast making the nearest landfall Prince of Wales Island which is approximately 160 km away. Assuming a drift velocity of 30 km/day gives a minimum travel time of on the order of 5 days.

30 m^3 - In the relatively large area of Viscount Melville Sound, this spill is small in scale and would probably not reach shore as a coherent slick.

300 m^3 - The size of this slick is small compared to the dimensions of Viscount Melville Sound, but could be significant in size compared with coastal features in a minimum travel time situation.

3,000 m^3 - Although still small compared to the dimensions of the Sound, this slick size is likely to strike land and impact significant amounts of shoreline.

30,000 m^3 - It is likely that a spill of this size would strike land at some point, the most likely locations being south and east of the spill site. Given the large area of Viscount Melville Sound, it is unlikely that the slick would extend over a great enough distance to cause significant coverage of the Sound. However, if the slick moved east into Barrow Strait, this could be a concern.

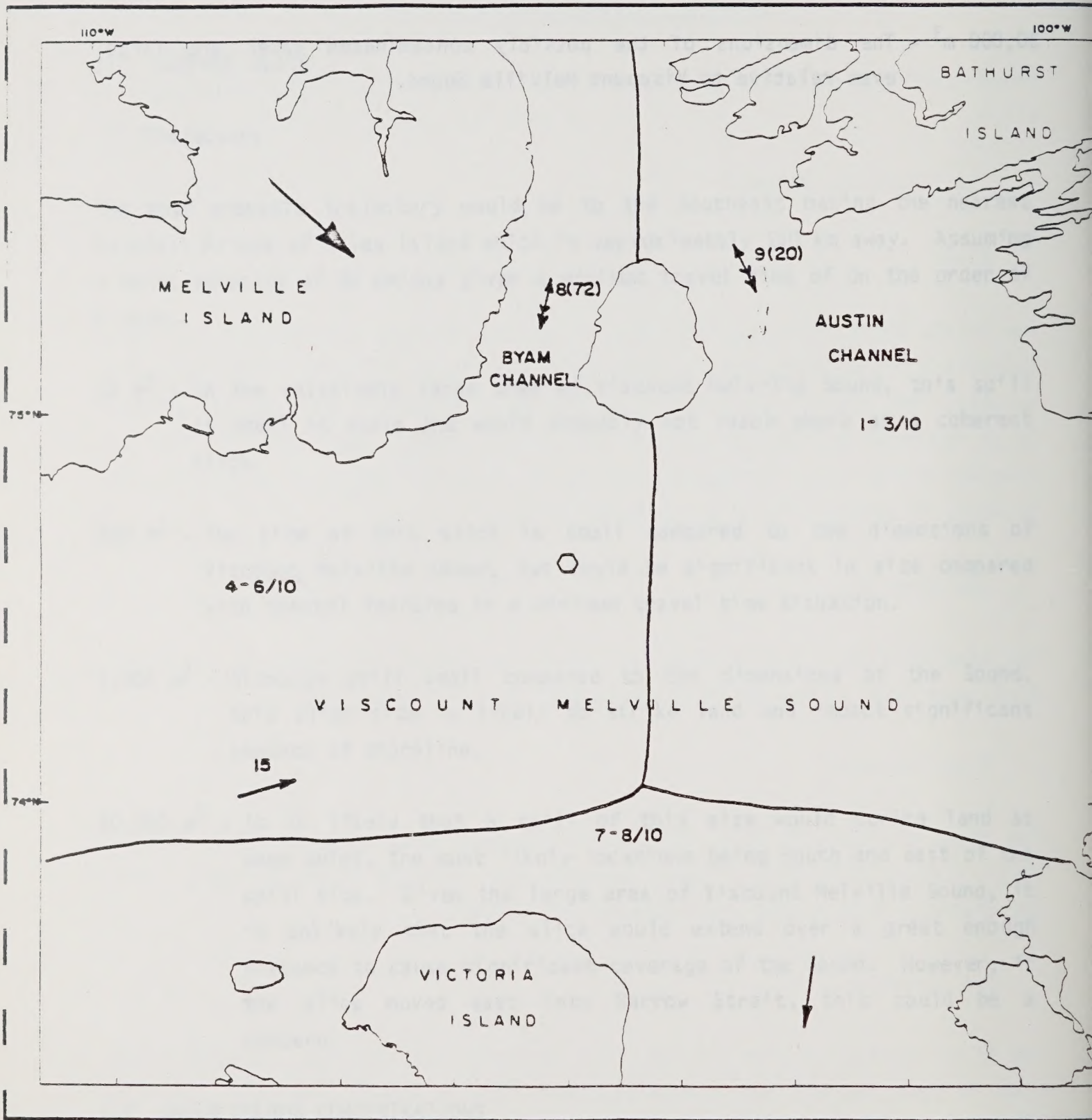
III WATER COLUMN CONCENTRATIONS

30-300 m^3 - In a large area such as this, the volume contaminated would probably be negligible.

3,000 m^3 - The dimensions of the possibly contaminated water are large even relative to Viscount Melville Sound.

30,000 m^3 - The dimensions of the possibly contaminated water are large even relative to Viscount Melville Sound.

HYPOTHETICAL SLICK MOVEMENT



SITE 4 : VISCOUNT MELVILLE SOU

Spill Volume
30 m^3
300 m^3
3000 m^3
30000 m^3

Slick Diameter
- 1.8 km
— 5.6 km
——— 18 km
——————— 45 km

Diameter 100 ppb Contamination
- 4.1 km
—— 13.0 km
——————— 41 km
——————————————— 130 km

SITE 5: SVERDRUP BASIN

Information is very sparse; one map has been included showing area of winter polynyas in Penny Strait.

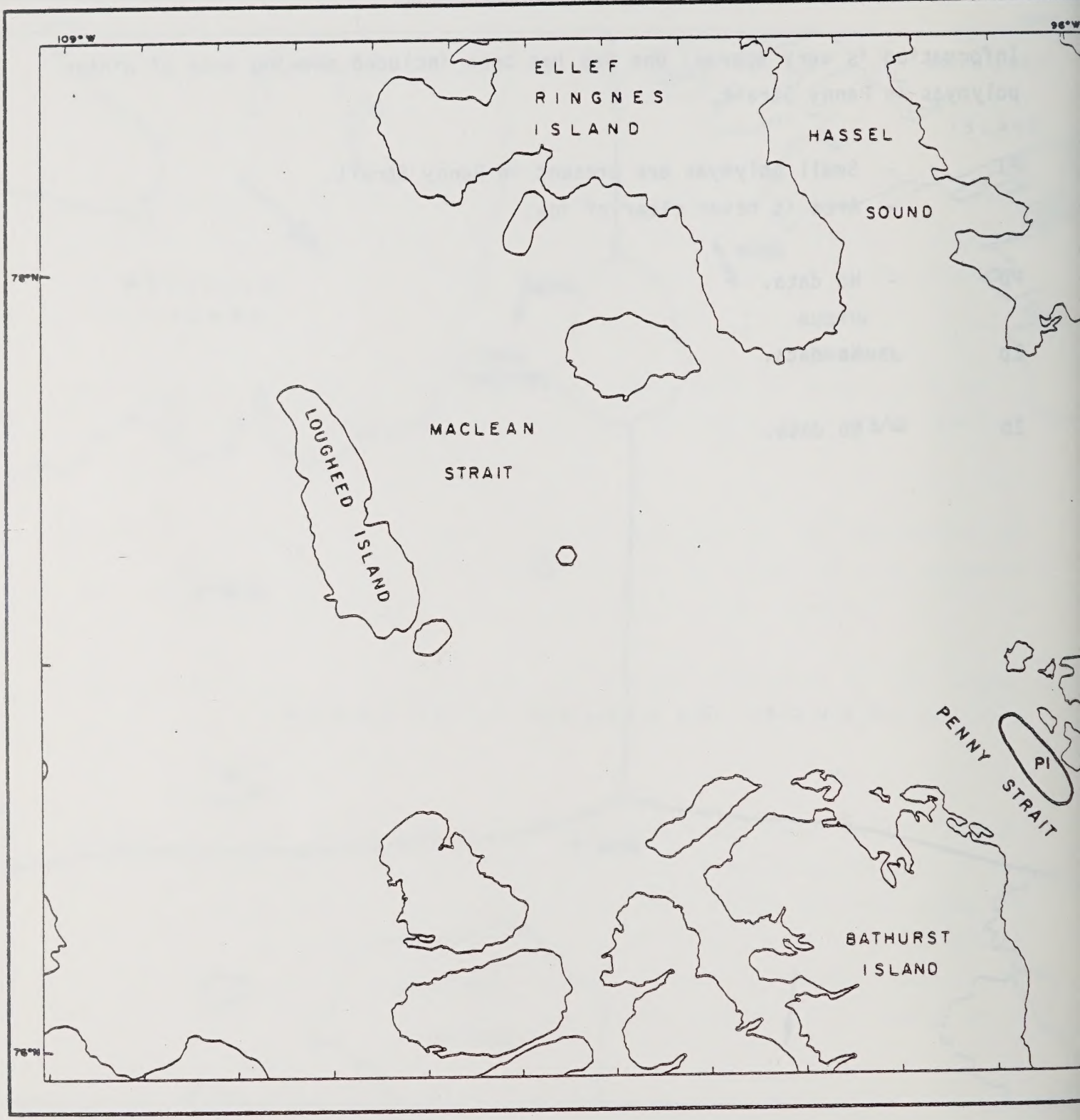
Pl - Small polynyas are present in Penny Strait.
- Area is never clear of ice.

Pp - No data.

Zp - No data.

Zb - No data.

PLANKTON/INVERTEBRATES



SITE 5 : SVERDRUP BA
OPEN-WATER PERIOD

FIG. B.3

SEABIRDS

SITE 5: SVERDRUP BASIN

Only the open-water period has been mapped; seabird activity during the ice-covered period is nil.

NMo:Br

- Southeast Ellef Ringnes Island. Nesting area of brant.

N:GG

- Hungry Bay - Devon Island. Colony glaucous gulls (20 prs.).

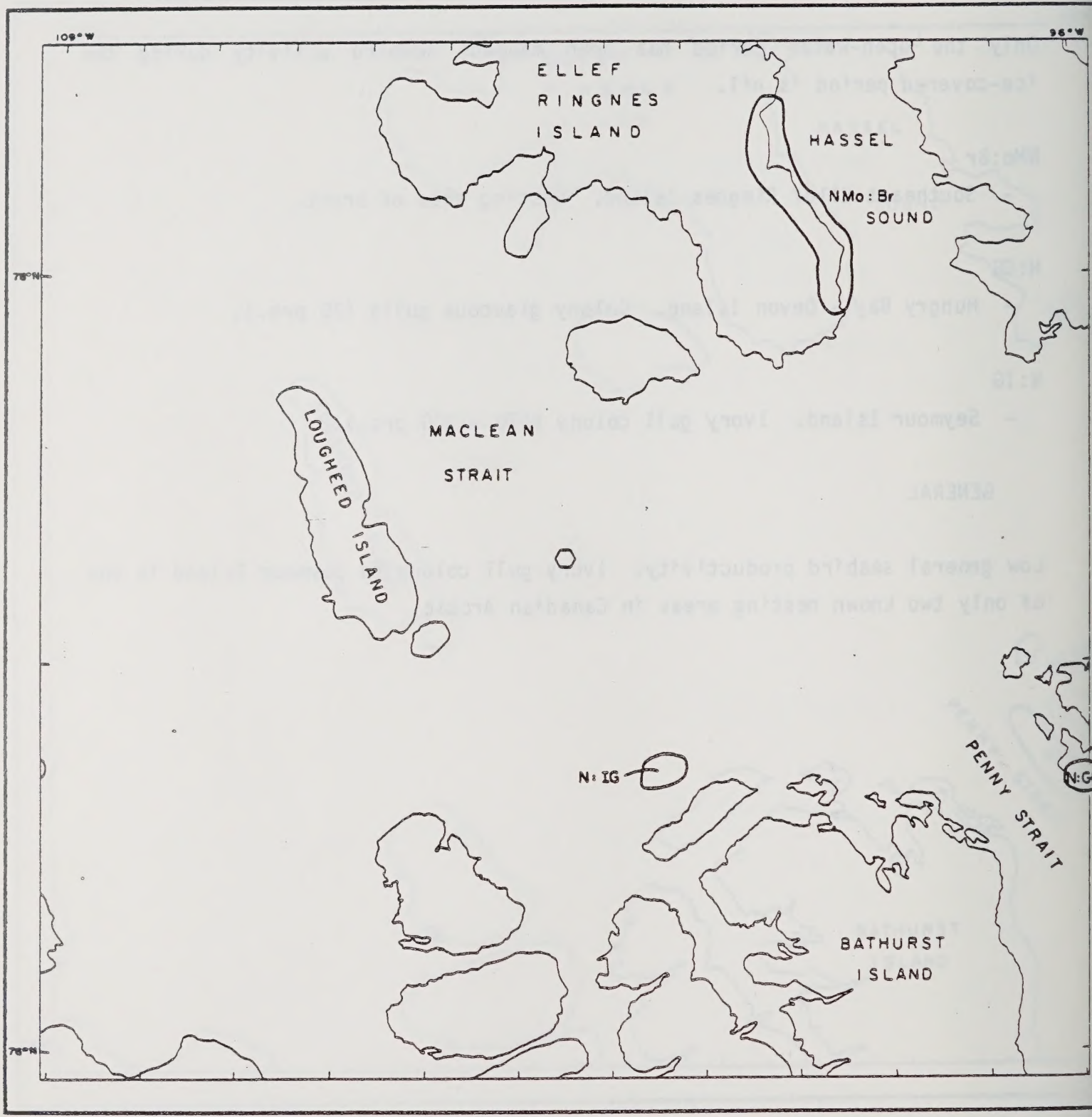
N:IG

- Seymour Island. Ivory gull colony (170 - 200 prs.).

GENERAL

Low general seabird productivity. Ivory gull colony on Seymour Island is one of only two known nesting areas in Canadian Arctic.

SEABIRDS



SITE 5 : SVERDRUP BAS
OPEN-WATER PERIOD

FIG. B.34

SITE 5: SVERDRUP BASIN

Very Limited Data

Only the ice-covered period has been mapped; distributions of marine mammals during the open-water period are unknown.

OPEN-WATER PERIOD:

(In September only, a patch of 5/10 ice cover appears south of Ellef Ringnes Island and west of Bathurst Island).

- The limited availability of open-water areas at this site reduces the possibility of this area being important to whales.
- No information on seals; region is important for polar bear which implies the presence of significant numbers of ringed seals.
- Bearded seals and walruses are present in Penny Strait.

ICE-COVERED PERIOD:

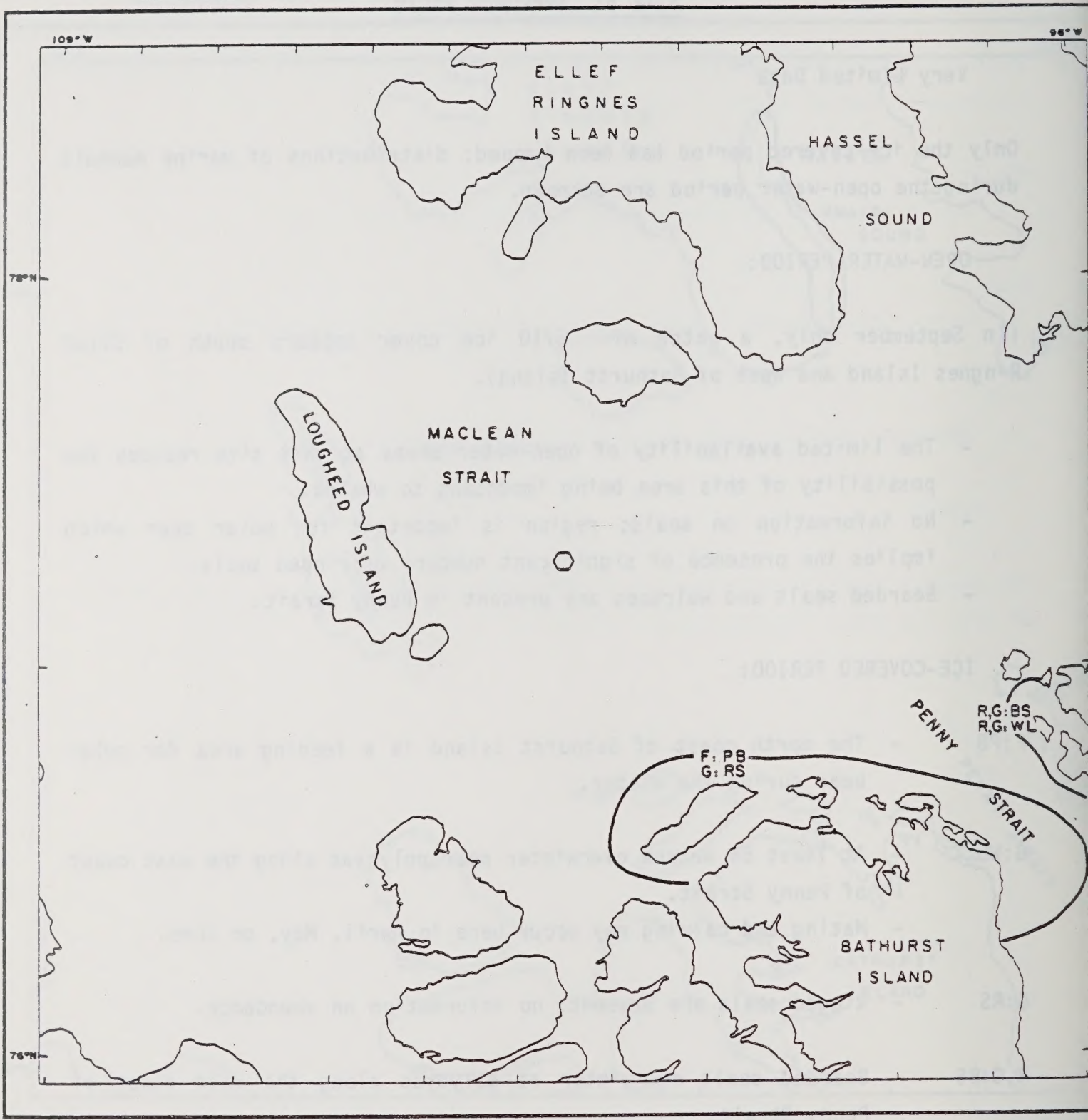
F:PB - The north coast of Bathurst Island is a feeding area for polar bear during the winter.

G:WL - At least 65 walrus overwinter near polynyas along the east coast of Penny Strait.
- Mating and calving may occur here in April, May, or June.

G:RS - Ringed seals are present; no information on abundance.

R,G:BS - Bearded seals overwinter at polynyas along the east coast of Penny Strait.
- Calving may occur here in late April.

MARINE MAMMALS



SITE 5 : SVERDRUP BA
ICE - COVERED PERIOD

FIG. B. 35

SITE 5: SVERDRUP BASIN

Open-water and ice-covered periods have been combined in one map for this site.

MARINE SPECIES

1. Polar Cod (Boreogadus saida)

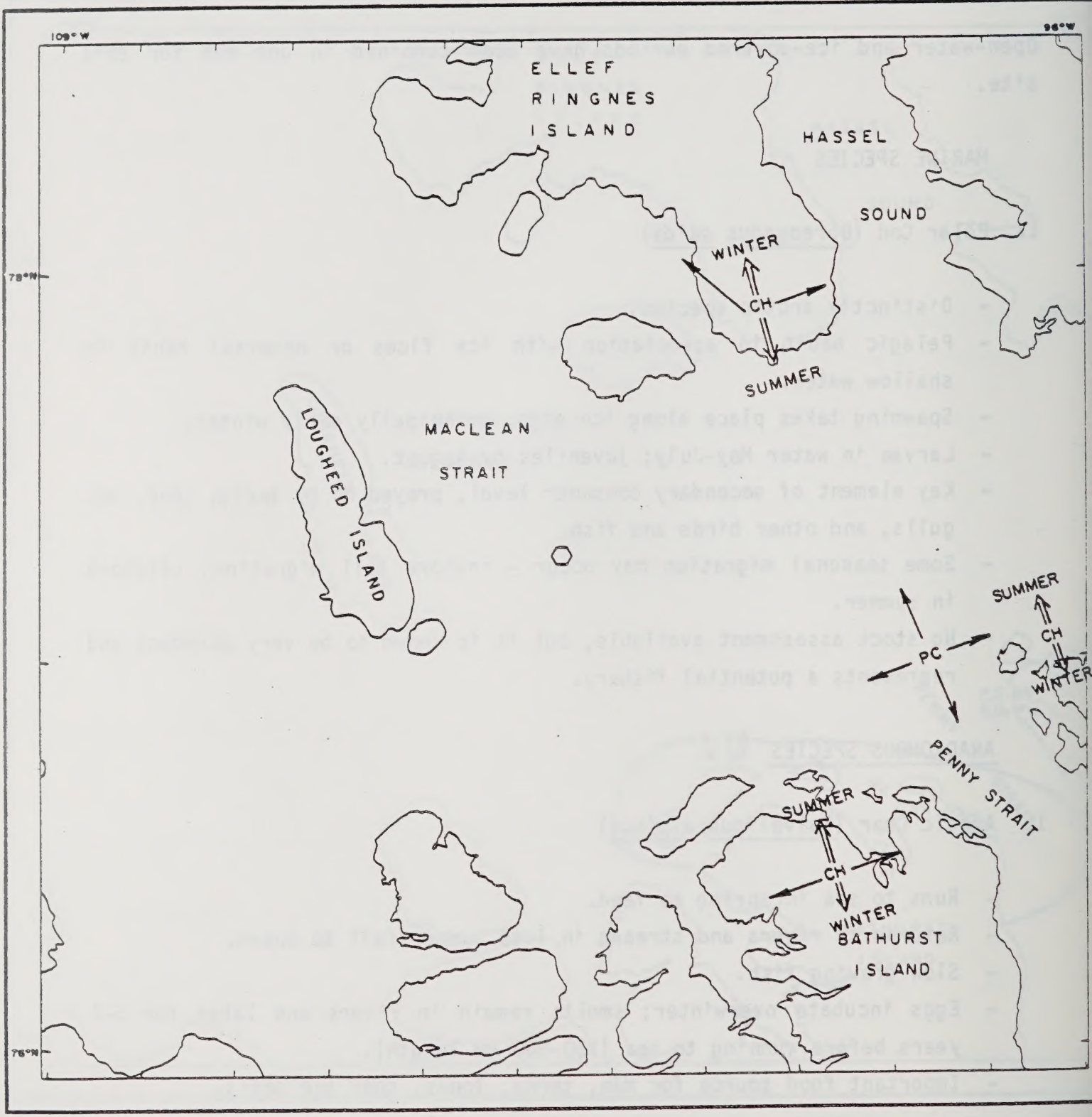
- Distinctly arctic species.
- Pelagic habit in association with ice floes or demersal habit in shallow water.
- Spawning takes place along ice edge, principally early winter.
- Larvae in water May-July; juveniles by August.
- Key element of secondary consumer level, preyed on by seals, char, sea gulls, and other birds and fish.
- Some seasonal migration may occur - inshore fall migration, offshore in summer.
- No stock assessment available, but it is known to be very abundant and represents a potential fishery.

ANADROMOUS SPECIES

1. Arctic Char (Salvelinus alpinus)

- Runs to sea in spring to feed.
- Returns to rivers and streams in late summer/fall to spawn.
- Slow growing fish.
- Eggs incubate overwinter; smolts remain in rivers and lakes for 5-7 years before running to sea (150-200 mm length).
- Important food source for man, terns, loons, char and seals.

FISHERY RESOURCES



SITE 5 : SVERDRUP BAS

FIG. B. 36

SITE 5: SVERDRUP BASIN

No major communities within site area. A base camp exists at Rea Point with a population of 100 (1978). No hunting, trapping, or fishing takes place, other than possibly for sport. Some polar bear hunting by Resolute hunters (as of 1977). There is no map prepared for this site.

HYPOTHETICAL SLICK MOVEMENT

SITE 5: SVERDRUP BASIN

One map has been prepared to show the environmental data with a key to spill sizes.

I ENVIRONMENTAL SUMMARY

Wind

Data from the permanent meteorological station at Isachsen on Ellef Ringnes Island are reported in the Canadian Normals, Volume 3. These data indicate a most probable wind direction of northeast to north through most of the year with a high probability of southwest winds in July. The mean monthly wind speeds vary from 360 to 550 cm/sec. in magnitude with the maximum occurring in June.

Ice Cover

Minimum ice cover occurs in September with an area between Lougheed Island and Ellef Ringnes covered 4-6/10, and the surrounding area covered 7-9/10 (shown on site map). Except for August and September, cover is 10/10.

Tidal Currents

Tidal currents have been measured under the ice in Penny Strait during April, 1976 and were also measured near Ellef Ringnes Island. Both measurements indicate weak mean currents on the order of 5 cm/sec.

Net Currents

Current measurements and ice drift observations indicate generally weak (1-6 cm/sec.) mean currents into Sverdrup Basin from the north and west.

II SURFACE SLICK

Trajectory

The oil would tend to move with the ice in a generally south and east direction at a maximum rate of perhaps 30 km/day with a more usual drift being something less than 10 km/day.

General

These waters are generally heavily ice infested year-round so that the assumptions inherent in the spreading analysis are never reasonable. There is no indication that the predicted dimensions are even order of magnitude correct, so it is recommended that these results not be applied to this situation.

III WATER COLUMN CONCENTRATION

30 m^3 - Surface extent is small in scale relative to open areas and most coastal features.

300 m^3 - Similar in scale to most coastal features.

3,000 m^3 - Large with respect to coastal features, significant in scale with respect to Sverdrup Basin.

30,000 m^3 - Similar in scale to Sverdrup Basin.

HYPOTHETICAL SLICK MOVEMENT

SITE 5 : SVERDRUP BAS

Spill Volume
30 m³
300 m³
3000 m³
30000 m³

Slick Diameter
1.8 km
5.6 km
18 km
45 km

Diameter 100 ppb Contamination
4.1 km
13.0 km
41 km
130 km

FIG. B.37

SITE 6: ALLISON INLET

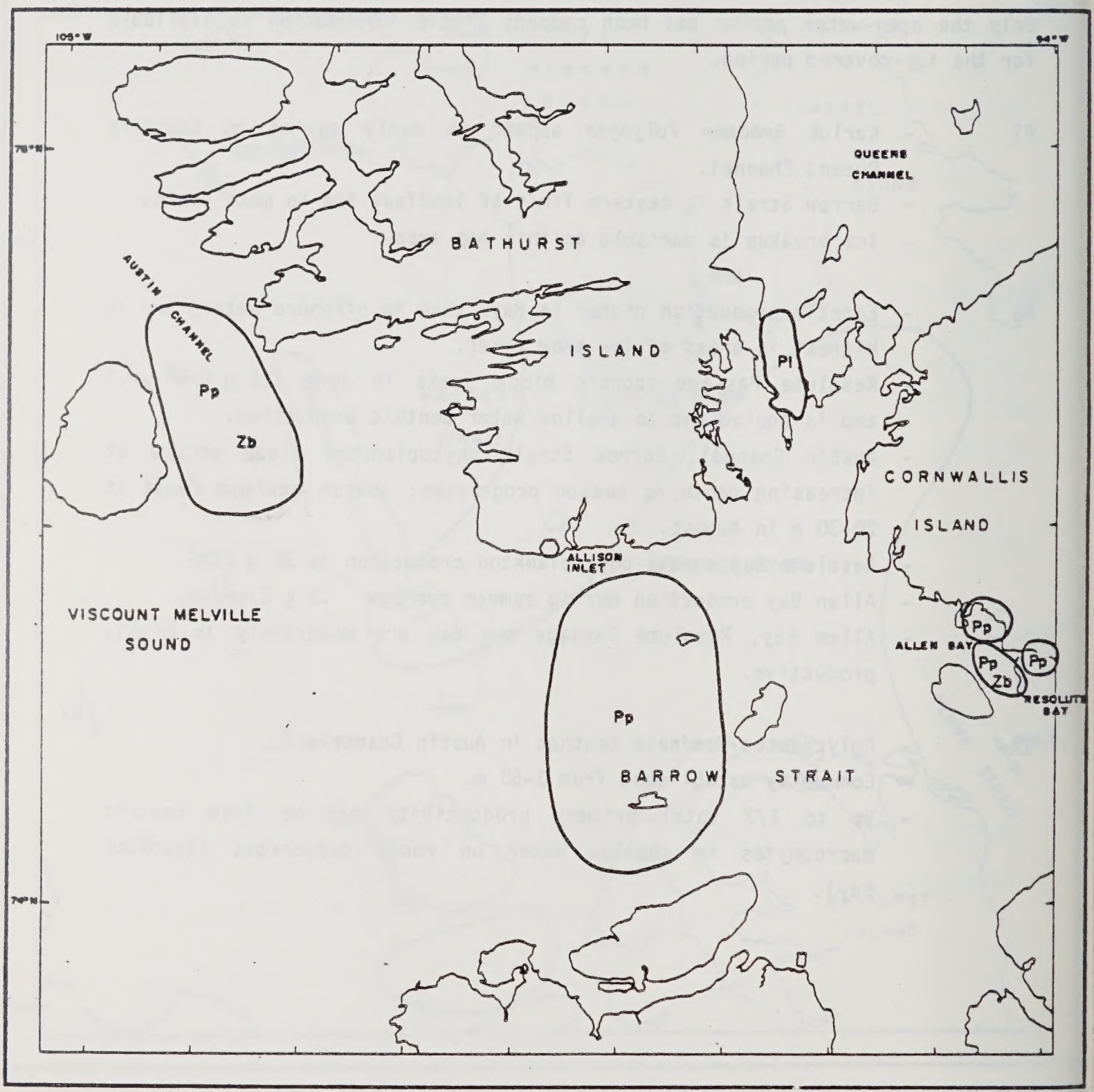
Only the open-water period has been mapped; little information is available for the ice-covered period.

Pl
- Karluk Brooman Polynyas appear in early spring in southern Queens Channel.
- Barrow Strait is eastern limit of landfast ice in most years.
- Ice breakup is variable on this map area.

Pp
- Epontic production higher in bays than in offshore waters and is highest in areas of low snow cover.
- Resolute Passage epontic bloom peaks in June (16 g $C/m^2/yr.$) and is equivalent to shallow water benthic production.
- Austin Channel, Barrow Strait phytoplankton bloom occurs at increasing depth as season progresses; season maximum found at 20-30 m in August.
- Resolute Bay annual phytoplankton production is 32 g C/m^2.
- Allen Bay production during summer average .2 g $C/m^2/day$.
- Allen Bay, Resolute Passage and Bay are moderately to highly productive.

Zb
- Polychaetes dominate benthos in Austin Channel.
- Community established from 3-50 m.
- Up to 1/3 total primary productivity may be from benthic macrophytes in shallow water on rocky substrates (Resolute Bay).

PLANKTON/INVERTEBRATES



SITE 6 : ALLISON INLET
OPEN-WATER PERIOD

FIG. B.38

SEABIRDS

SITE 6: ALLISON INLET

Only the open-water period has been mapped for this site; little seabird activity occurs during the ice-covered period.

OPEN-WATER PERIOD

NMo:Br

- Bracebridge Inlet - Bathurst Island. Nesting and moulting area for brant.

NF:Wf

- Polar Bear Pass - Bathurst Island. Important area - nesting and feeding area for large numbers of waterfowl especially king eiders and oldsquaws. (42 species of birds occur; 26 known to nest).

NS:EdAT

- Polynyi - Crozier Strait. Heavy use in some years (June) by eiders waiting to nest inland. Terns nesting onshore, coastal use by Arctic terns and oldsquaws.

S:EdOSAT

- Little Cornwallis Island. In late summer, northwest section important for Arctic terns, oldsquaws and eiders.

N:KW

- Houston Steward Island - Queen's Channel. Black-legged kittiwakes (500 prs.).

NS:KW

- Browne Island - Staging area for black-legged kittiwakes. June - August. Nesting black-legged kittiwakes (1000 prs.).

S:Sb

- West Barrow Strait. Staging area along ice edges used by seabirds in the spring (edge varies year to year).

N:GuTM

- Palmerston Point - Russell Island. Nesting colony of glaucous gulls (12 prs.), glaucous and/or Thayer's gulls (30 prs.) and thick-billed murres (5 prs.).

N:GGTGBG

- Cape Briggs - Prince of Wales Island. Nesting colony of glaucous gulls (32 prs.), Thayer's gulls (11 prs.), black guillemots. (1 pr.).

Mo:OS(2)

- Baring Channel. Moulting oldsquaws in August.

N:KERP

- Northwest Cornwallis Island. Important area for nesting king eiders (300 prs.) and red phalaropes (1500 individuals).

Mo:OS(1)

- Pullen Strait. Moulting area for oldsquaws.

S:Ed

- Polynya - Baillie Hamilton Island. Spring staging area for eiders.

N:KWGGBG

- Washington Point - Baillie Hamilton Island. Nesting black-legged kittiwakes (3000 prs.), glaucous gulls and black guillemots (< 100 prs. each) - May to end September.

N:TGBG

- Griffith Island - Barrow Strait. Small colony of Thayer's gulls and black guillemots (10 prs.).

Sb

- Resolute Passage - Barrow Strait and south Wellington Channel. Ice edges heavily used by seabirds in spring (June).

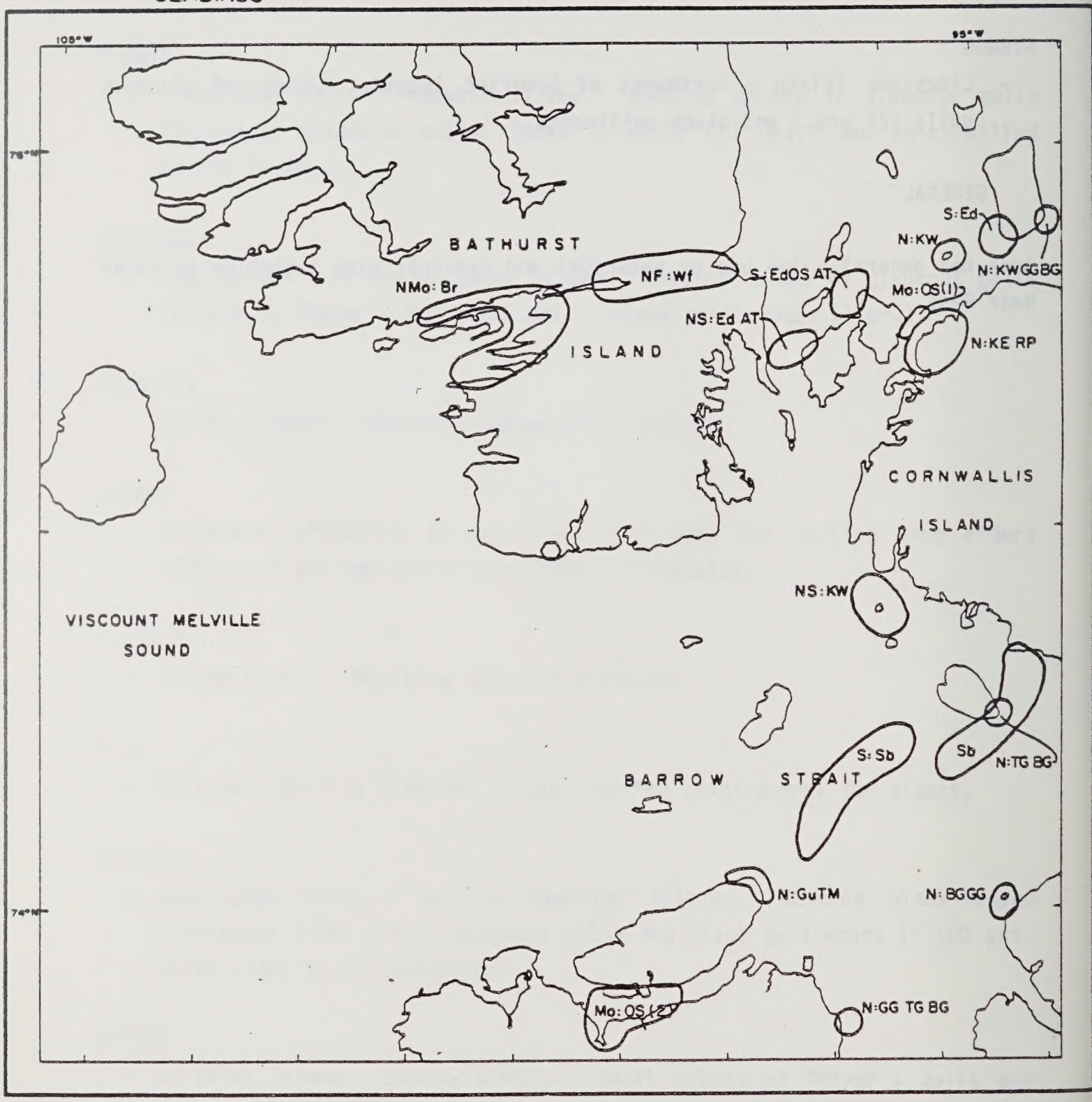
N:BGGG

- Limestone Island - northwest of Somerset Island. Colony of glaucous gulls (25 prs.) and black guillemots.

GENERAL

Area has generally low use by waterfowl and seabirds with exception of Polar Bear Pass.

SEABIRDS



SITE 6 : ALLISON INLET
OPEN - WATER PERIOD

FIG. B.39

SITE 6: ALLISON INLET

Both open-water and ice-covered periods have been mapped for this site.

OPEN-WATER PERIOD:

Mo:RS
- High densities of ringed seals haul out on landfast ice in early summer to moult; mouth of Peel Sound and northeast tip Russell Island.
- After the moulting period, ringed seals disperse throughout the site and can be found both along the coast and offshore.

G:BS
- Bearded seals are not as abundant as ringed seals but are common in shallow-water areas which provide food during the open water period.

M:WL
- 150 to 200 walruses migrate along the south shore of Cornwallis Island to the Crozier Strait area in late July and early August.

G:WL
- Summer feeding area in the Crozier Strait area from mid-July to mid-September for about 300 walrus.

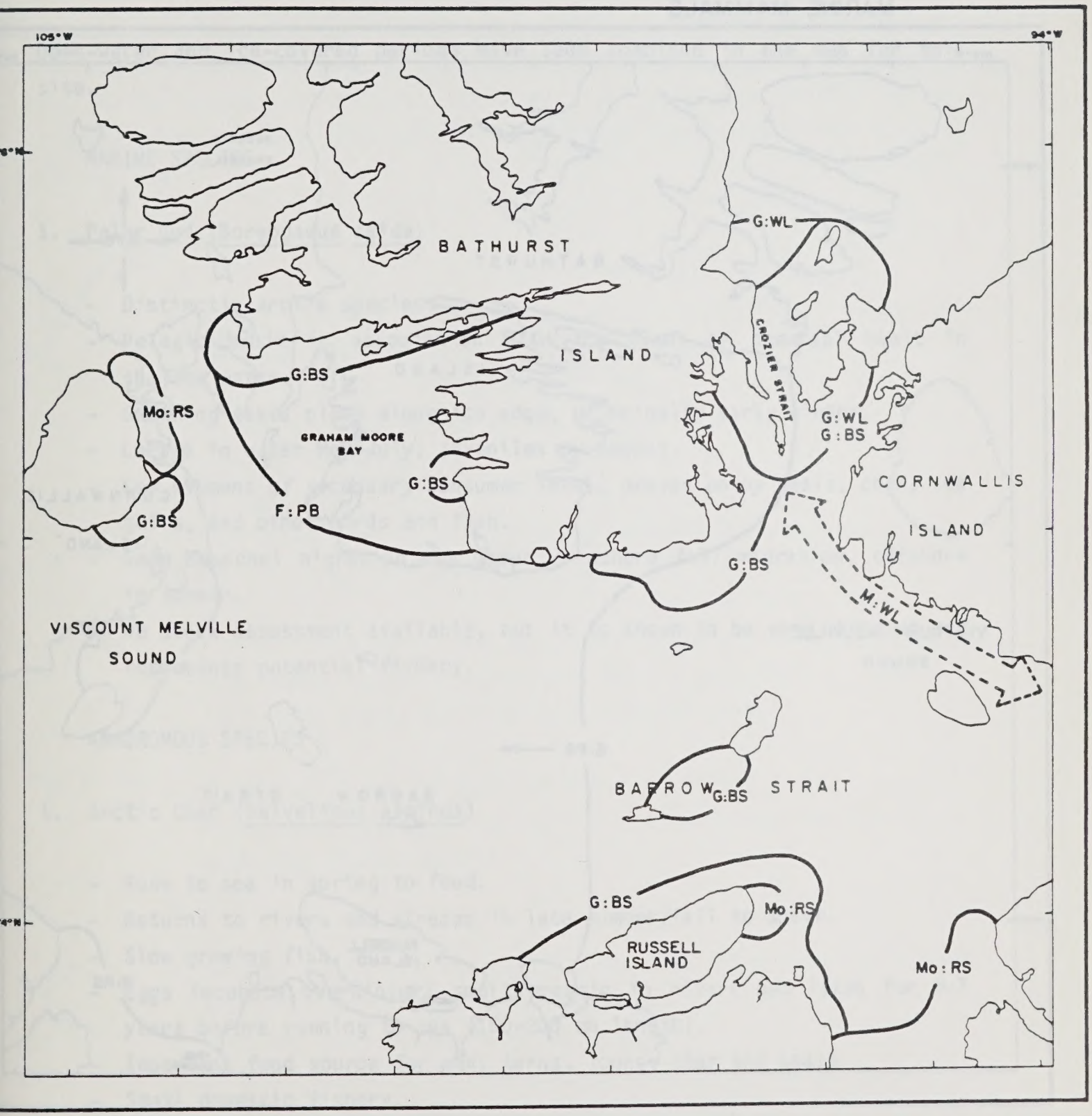
F:PB
- Graham Moore Bay is an important feeding area for polar bear in the spring and early summer while landfast ice still exists.

ICE-COVERED PERIOD:

R:RS
- High densities of birth lairs on landfast ice occur in late March and early April when ringed seals pup; Peel Sound area and south of Cornwallis Island are the areas of greatest concentrations.

G:PB - Polar bears are widely dispersed over the ice in Barrow Strait and northwards into Queen's Channel during the winter.

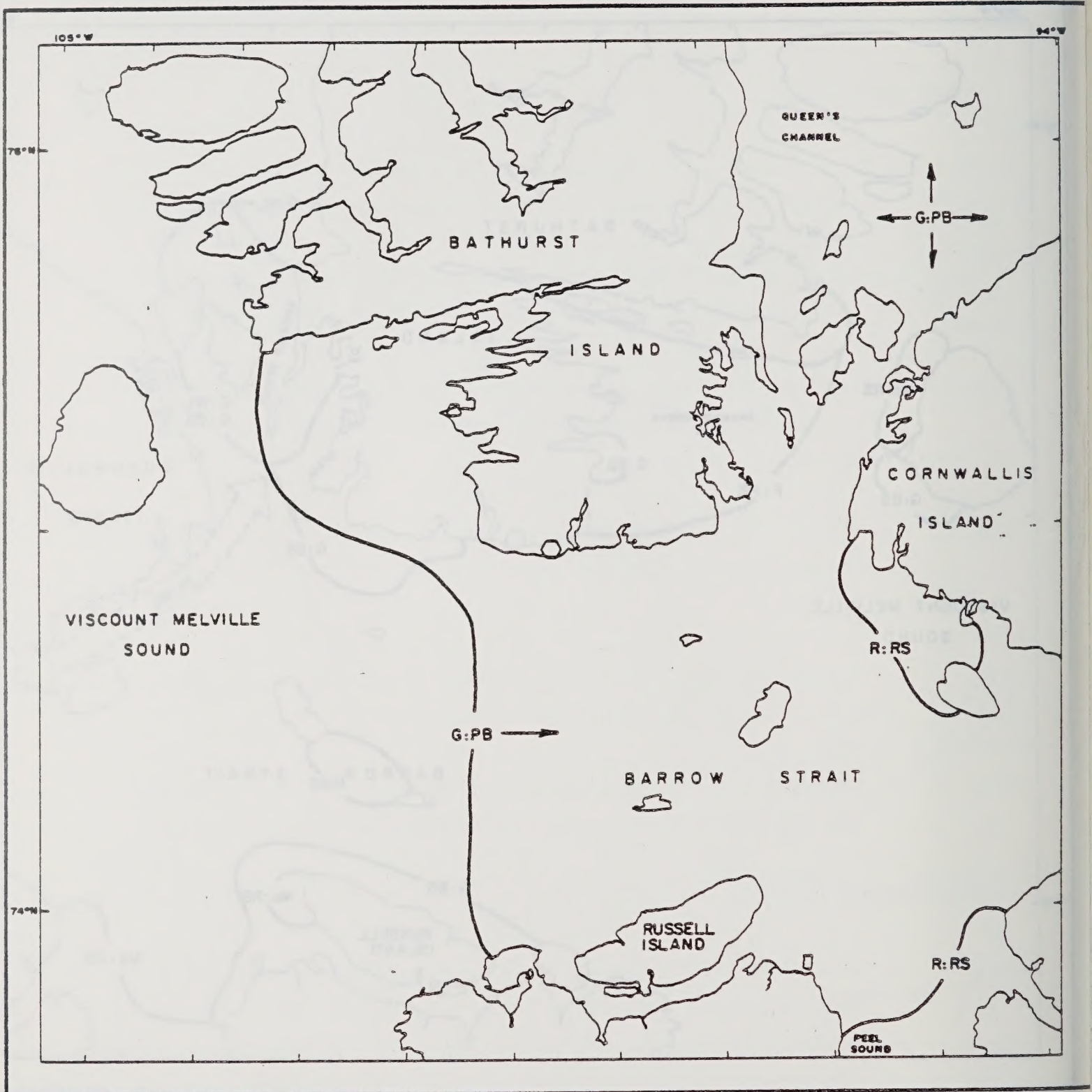
MARINE MAMMALS



SITE 6 : ALLISON INLET
OPEN - WATER PERIOD

FIG. B.40

MARINE MAMMALS



SITE 6 : ALLISON INLET
ICE-COVERED PERIOD

FIG. B.41

SITE 6: ALLISON INLET

Open-water and ice-covered periods have been combined in one map for this site.

MARINE SPECIES

1. Polar Cod (Boreogadus saida)

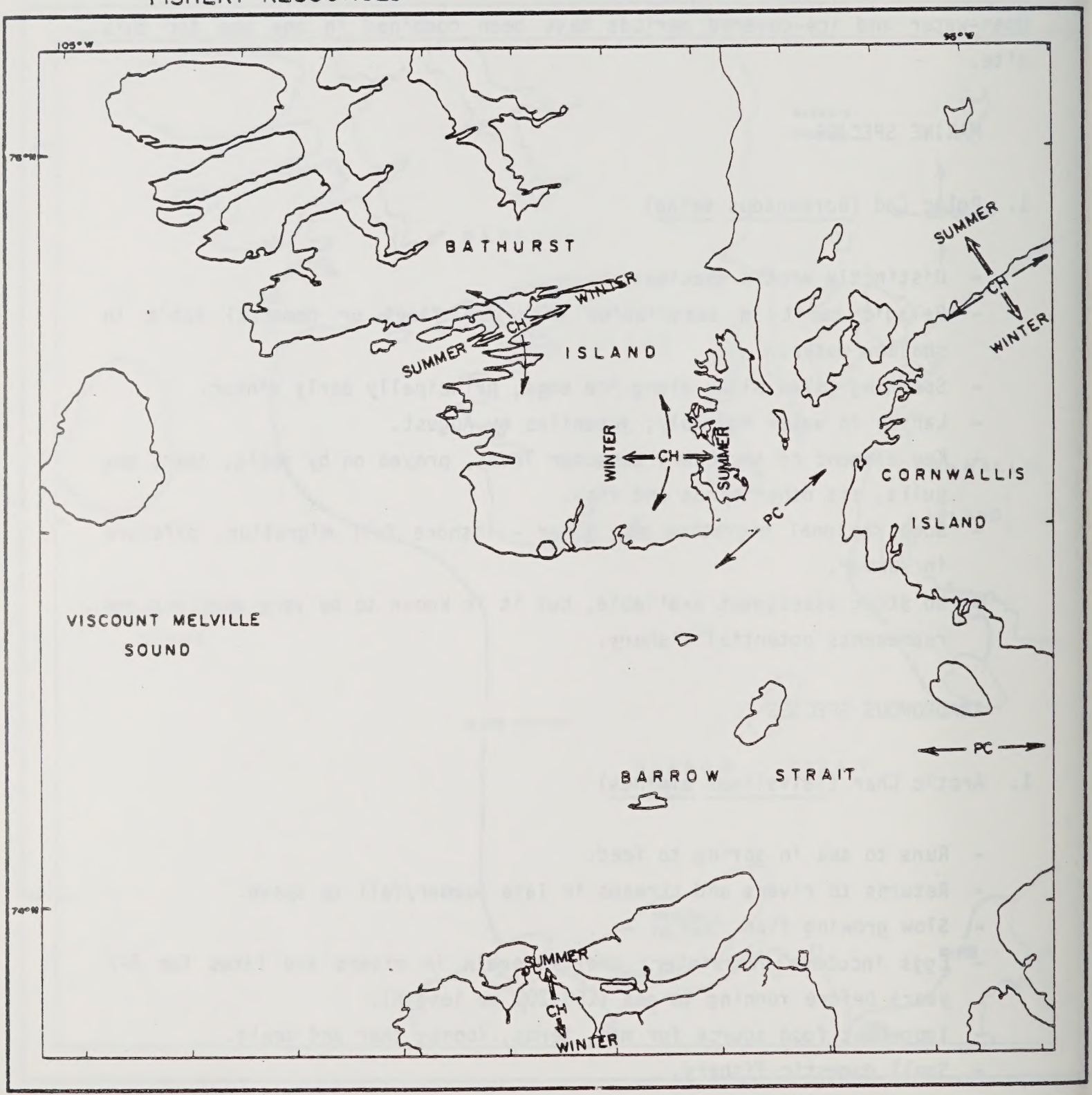
- Distinctly arctic species.
- Pelagic habit in association with ice floes or demersal habit in shallow water.
- Spawning takes place along ice edge, principally early winter.
- Larvae in water May-July; juveniles by August.
- Key element of secondary consumer level, preyed on by seals, char, sea gulls, and other birds and fish.
- Some seasonal migration may occur - inshore fall migration, offshore in summer.
- No stock assessment available, but it is known to be very abundant and represents potential fishery.

ANADROMOUS SPECIES

1. Arctic Char (Salvelinus alpinus)

- Runs to sea in spring to feed.
- Returns to rivers and streams in late summer/fall to spawn.
- Slow growing fish.
- Eggs incubate overwinter; smolts remain in rivers and lakes for 5-7 years before running to sea (150-200 mm length).
- Important food source for man, terns, loons, char and seals.
- Small domestic fishery.

FISHERY RESOURCES



SITE 6 : ALLISON INLET

FIG. B.42

SITE 6: ALLISON INLET

There are no communities on the island, but the area is used by the Resolute natives for hunting and fishing. Resolute - 556 residents (1978). Harvest figures given are for Resolute and may include areas other than Bathurst Island itself.

MAMMALS

AF
- Arctic fox are trapped along shore of Bathurst Island and offshore islands, November - April, 339/yr.

PB
- Bathurst Island serves as one of the major polar bear hunting areas in the Arctic.
- Average 62/yr.
- Hunting October to January along southern coast and February to May across Barrow Strait.

W
- A significant center for beluga and narwhal.
- Late summer, early fall harvests (July - September).
- Average 28 beluga and 4 narwhal taken per year.

RS
- Ringed seals are the most important resource.
- Hunted year round; during caribou and bear trips and in July and September in open water.
- 376/yr.

BS
- Bearded seals are hunted in same area as ringed seals (see maps), primarily late May to June.
- Some are taken during ice-free season.
- 26/yr.

HS
- Harp seals are taken close to Resolute only during late summer.
- Average of 13/yr.

WL
- Small numbers of walrus are taken during seal and whale hunts - spring and fall.
- 10/yr.

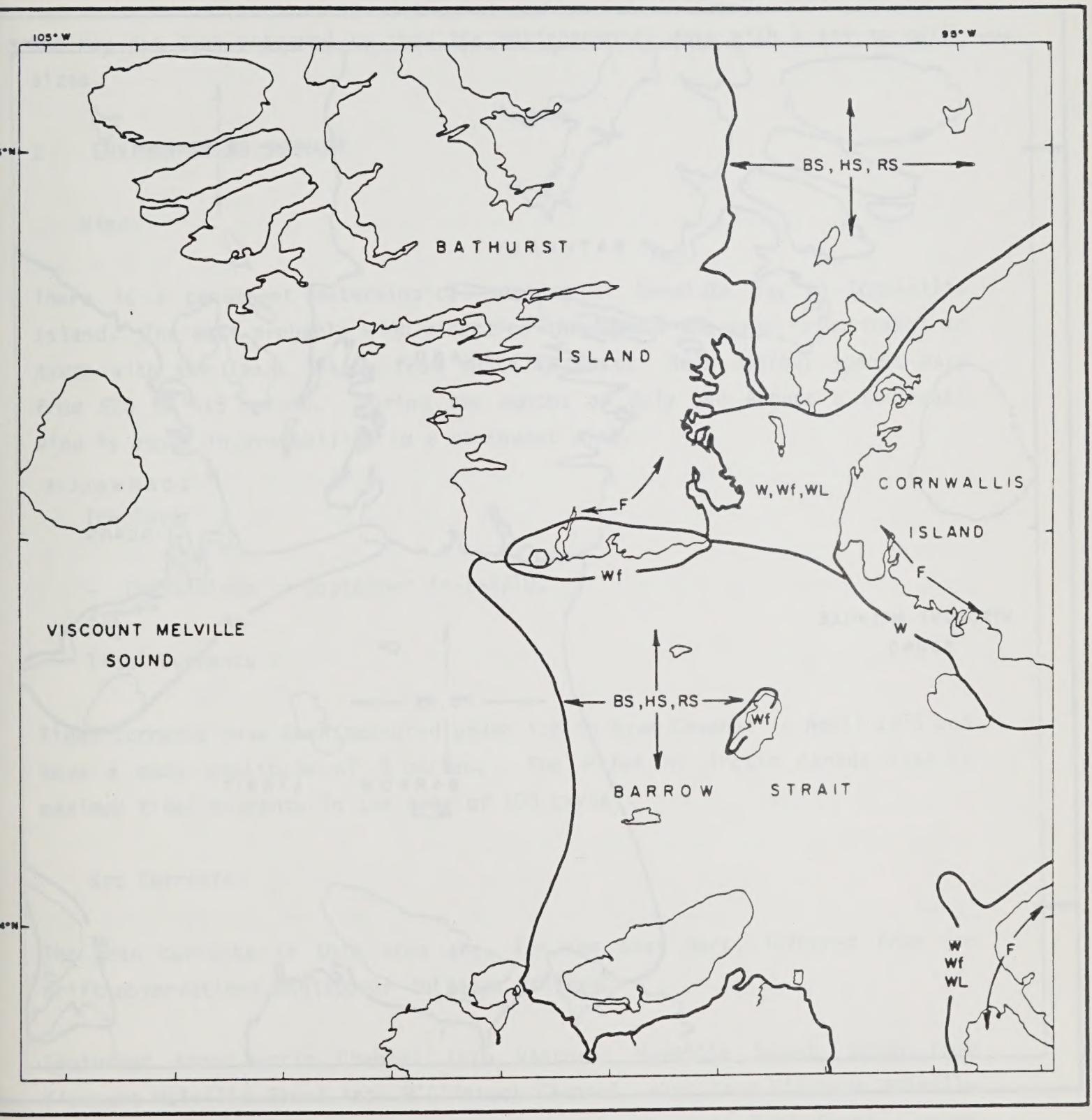
BIRDS

Wf
- Eider ducks nest along east and southeast coasts of Bathurst Island and on offshore islands.
- Harvested along this coast, usually during sealing.
- Shot in leads in spring and occasionally in open water.
- Small amount of egging takes place.
- Average 28/yr.

FISHERIES

F
- Char is a major species utilized by Resolute natives.
- Found in lakes on east central area and the southeast coast.
- Fished generally during early summer (May-June), but may continue until September.
- Domestic catch, 1976 - 1125 kg.
- No commercial fishery.

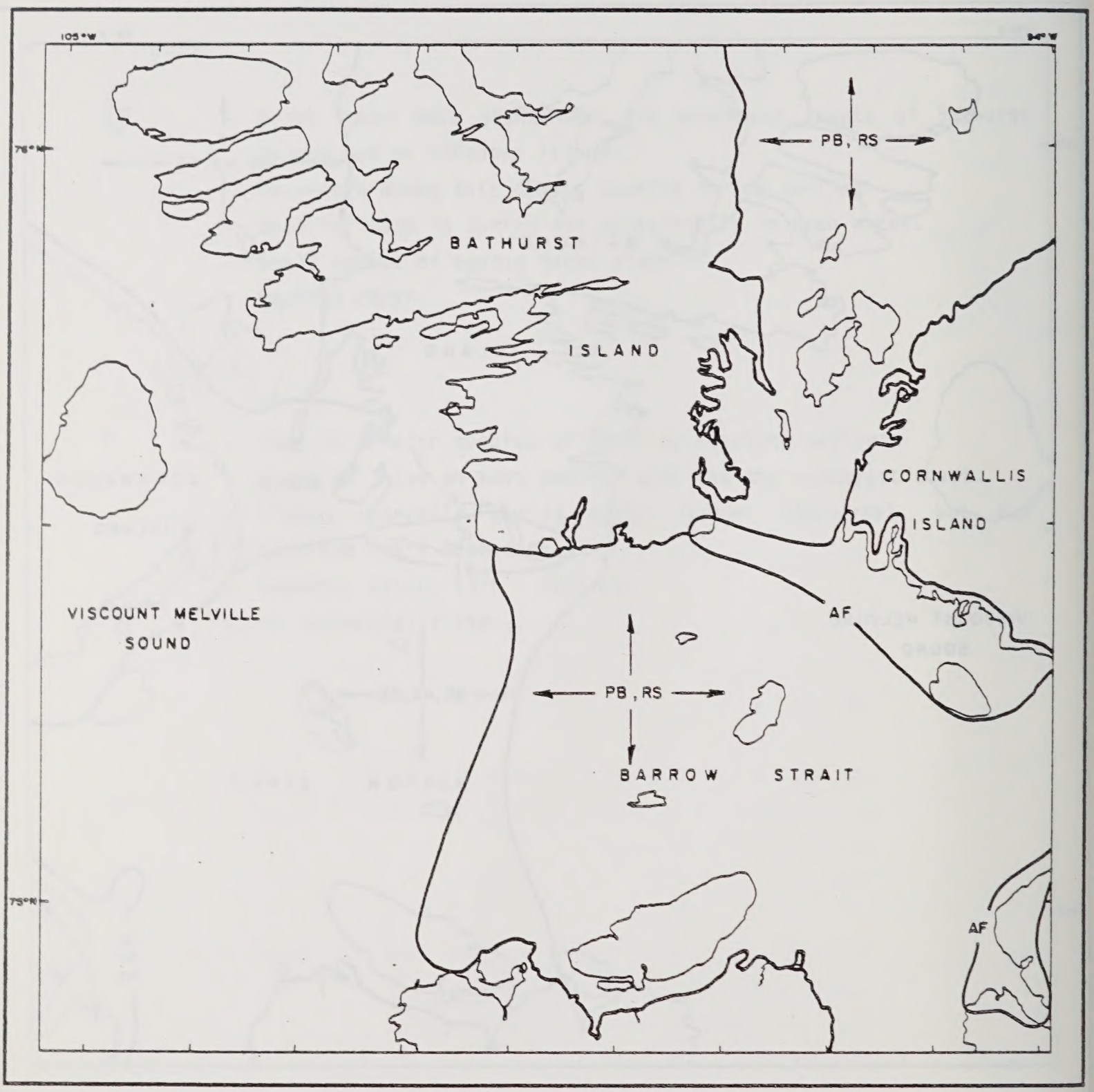
HUNTING AND FISHING



SITE 6 : ALLISON INLET
OPEN-WATER PERIOD

FIG. B. 43

HUNTING AND FISHING



SITE 6 : ALLISON INLET
ICE - COVERED PERIOD

FIG. B.44

HYPOTHETICAL SLICK MOVEMENT

SITE 6: ALLISON INLET

One map has been prepared to show the environmental data with a key to spill sizes.

I ENVIRONMENTAL SUMMARY

Wind

There is a permanent meterological station at Resolute Bay on Cornwallis Island. The most probable wind direction throughout the year is northwest to north with the least likely from south to west. Mean monthly speeds vary from 520 to 615 cm/sec. During the months of July and August a southeast wind is equal in probability to a northwest wind.

Ice Cover

- The minimum in September is 1-3/10.

Tidal Currents

Tidal currents have been measured under ice in Byam Channel in April 1976 and have a mean amplitude of 9 cm/sec. The Pilot of Arctic Canada reports maximum tidal currents in the area of 100 cm/sec.

Net Currents

The mean currents in this area are, for the most part, inferred from ice drift observations and appear to be as follows:

Southwest from Austin Channel into Viscount Melville Sound, south from Viscount Melville Sound into M'Clintock Channel, east from Viscount Melville Sound into Barrow Strait, south from Barrow Strait into Peel Sound. north and east currents have been observed southwest of Cornwallis Island

indicating the possibility of a gyre north of Peel Sound. The currents in Barrow Strait south of Cornwallis Island appear quite confused and of small magnitude but probably have a net eastward drift. The Pilot of Arctic Canada indicates a flow north into McDougall Sound from Barrow Strait.

II SURFACE SLICK

General

This site is located on the south shore of Bathurst Island. In this case even a relatively small spill might impact quite a large area. This is due to two considerations:

1) The lack of reduction of volume by weathering before impact.
2) The geometry of spreading along a coast.

A small spill occurring directly on the coast might never leave the coast. For larger spills, a portion will likely move off the coast. The impact to Bathurst Island is obvious. The following discussions assume the spill occurs near the coast and does not immediately impact Bathurst.

Trajectory

The most probable trajectory appears to be southeast with the mean current and prevailing wind. The closest landfall is among the islands in the Barrow Strait the closest being approximately 45 km away. This indicates a minimum travel time of approximately three days.

30 m^3 - Small in scale relative to the main features of the area and unlikely to reach land (other than Bathurst Island) before being highly weathered.

300 m^3 - Small in scale relative to open water but significant in scale relative to size of islands.

3,000 m^3 - Spills of this size would significantly contaminate areas of coastal and island shorelines and are significant in scale relative to inter-island distances.

30,000 m^3 - Of same scale as inter-island distances of Barrow Strait and larger in scale than the majority of islands.

III WATER COLUMN CONTAMINATION

General

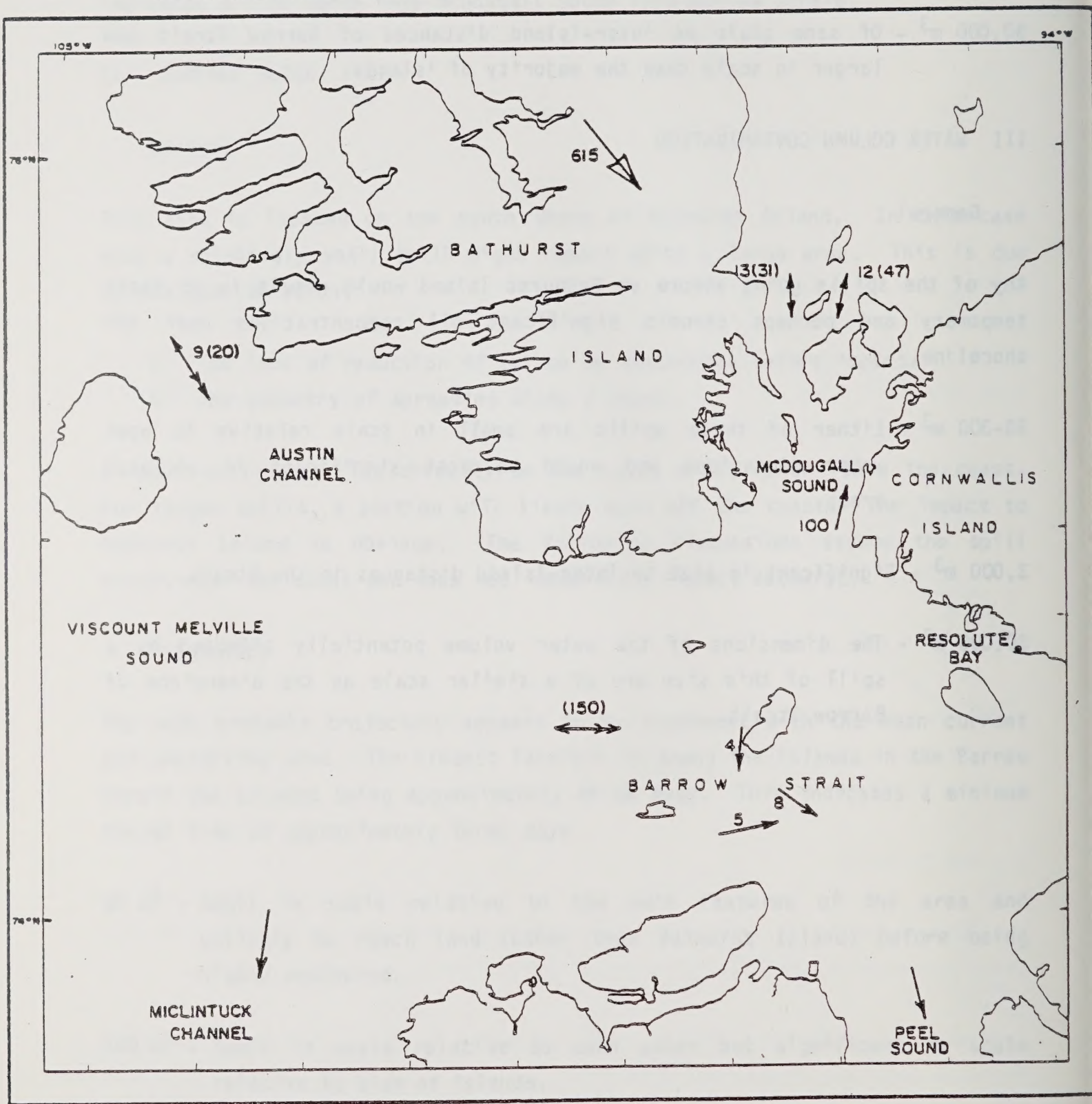
Any of the spills going ashore on Bathurst Island would result in at least temporary and perhaps chronic significant oil concentrations near the shoreline.

30-300 m^3 - Either of these spills are small in scale relative to open water dimensions and would be most significant in enclosed areas.

3,000 m^3 - Significant in size to inter-island distances in the Strait.

30,000 m^3 - The dimensions of the water volume potentially affected by a spill of this size are of a similar scale as the dimensions of Barrow Strait.

HYPOTHETICAL SLICK MOVEMENT



SITE 6 : ALLISON INLE

Spill Volume
30 m^3
300 m^3
3000 m^3
30000 m^3

Slick Diameter
1.8 km
5.6 km
18 km
45 km

Diameter 100 ppb Contamination
4.1 km
13.0 km
41 km
130 km

FIG. B.45

PLANKTON/INVERTEBRATES

SITE 7: CAPE LIDDON

This map area includes western Lancaster Sound, an area of high productivity. Only information for the open-water period has been mapped; information for the ice-covered period is limited.

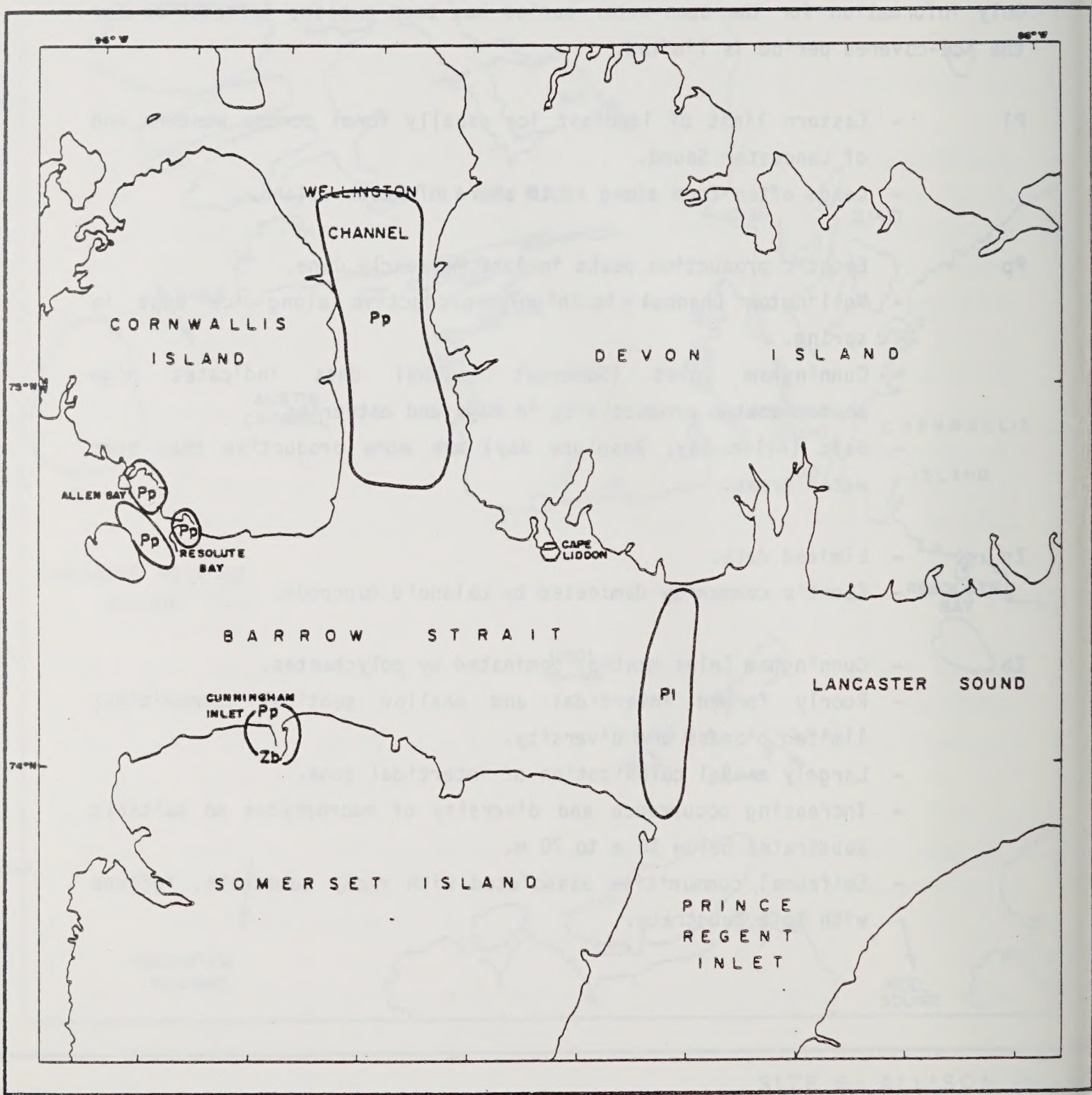
Pl
- Eastern limit of landfast ice usually forms across western end of Lancaster Sound.
- Leads often form along south shore of Devon Island.

Pp
- Epontic production peaks in late May/early June.
- Wellington Channel is highly productive along ice edge in spring.
- Cunningham Inlet (Somerset Island) data indicates high phytoplankton productivity in bays and estuaries.
- Bays (Allen Bay, Resolute Bay) are more productive than open water areas.

Zp
- Limited data.
- Epontic community dominated by calanoid copepods.

Zb
- Cunningham Inlet benthos dominated by polychaetes.
- Poorly formed intertidal and shallow subtidal communities; limited biomass and diversity.
- Largely annual colonization of intertidal zone.
- Increasing occurrence and diversity of macrophytes on suitable substrates below 10 m to 70 m.
- Epifaunal communities associated with rocky substrate, infauna with soft substrate.

PLANKTON/INVERTEBRATES



SITE 7 : CAPE LIDDON
OPEN-WATER PERIOD

FIG. B.46

SEABIRDS

SITE 7: CAPE LIDDON

Only the open-water period has been mapped for this site; activity during the ice-covered period is nil.

OPEN-WATER PERIOD:

N:TGBG

- Griffith Island - Barrow Strait. Small colony of Thayer's gulls and black guillemots (10 prs.).

Sb(1,2)

- Resolute Passage - Barrow Strait and south Wellington Channel. Ice edges heavily used by seabirds in spring.

SF:NF(1,2)

- Staging and feeding area for northern fulmars - August to September.

N:KWGG

- Separation Point - Cornwallis Island. Nesting black-legged kittiwakes (125 prs.) and glaucous gulls.

Gu/N:TG

- East Aston Bay - Somerset Island. Colony of Thayer's gulls (150 prs.). Other gulls, especially glaucous gulls, using the area.

N:TGGGBG

- Cunningham River - Somerset Island. Colony of Thayer's gulls (75 prs.), Nesting glaucous gulls (7 prs.), other gulls (15 prs.) and black guillemots (5 prs.).

Ed/F:NF

- Cunningham Inlet - Somerset Island. Concentrations of eiders in polynyas (early spring) and heavy feeding by northern fulmars.

FS:NFKWMu(1-5)

- East Garnier Bay, Elwin Bay, West Brodeur Peninsula, Radstock Bay, Cape Herd, Graham Harbour, Blaney Bay and Hobhouse Inlet west. Feeding and staging areas for northern fulmar and black-legged kittiwakes (summer and fall) and murres (spring).

N:BGGG(2)

- Cape Clarence - Somerset Island. Nesting area for black guillemots (200 prs.) and glaucous gulls (20 prs.).

N:SbGu(1)

- Prince Leopold Island. Nesting area for northern fulmars (62,000 prs.), thick-billed murres (86,000 prs.), black-legged kittiwakes (29,000 prs.), black guillemots (4,000 prs.) and glaucous gulls (200 prs.) - late April to end of September.

Sb(3)

- Barrow Strait. Large concentrations of seabirds, many from Prince Leopold colonies (ca. 300,000 individuals). Present from early spring until fall, ice edge heavily used in spring.

N:NFCEBG

- Cape Liddon - Devon Island. Colony of northern fulmars (62,000 prs.), thick-billed murres (86,000 prs.), black-legged kittiwakes (29,000 prs), black guillemots (4,000 prs.) and glaucous gulls (2,000 prs.) - late April to end of September.

N:SbGu(2)

- Hobhouse Inlet - Devon Island. Nesting area for northern fulmars (ca. 70,000 prs.). Glaucous and Thayers' gulls and black guillemot also breed (100 prs. each) - April to end of September.

N:BGGG(1)

- Limestone Island - Northwest of Somerset Island. Colony of glaucous gulls (25 prs.) and black guillemots.

F:TMKWNF

- Northeast Somerset Island. Spring and summer feeding areas for thick-billed murres, black-legged kittiwakes and northern fulmars.

FuKW

- Central Lancaster Sound. Large numbers of fulmars and kittiwakes present, although densities not as great as nearshore.

F:SbGu/N:GGSN

- Cape Horne to Wellingon Channel - Lancaster Sound. Feeding areas for northern fulmars, black guillemots, glaucous gulls, thick-billed murres, black-legged kittiwakes. Scattered colonies of glaucous gulls (10-30 prs. each) and inland colonies of greater snow geese (May to October).

NS:KW

- Browne Island. Staging area for black-legged kittiwakes June - August. Nesting black-legged kittiwakes (1000 prs.).

N:KERP

- Northwest Cornwallis Island. Important area for nesting king eiders (300 prs.) and red phalaropes (1,500 individuals).

Mo:OS

- Pullen Strait. Moulting area for oldsquaws.

S:EdOSAT

- Little Cornwallis Island. In late summer, northwest section important for Arctic terns, oldsquaws and eiders.

N:KW

- Houston Stewart Island - Queen's Channel. Nesting black-legged kittiwakes (500 prs.).

N:KWGGBG

- Washington Point - Baillie Hamilton Island. Nesting black-legged kittiwakes (3,000 prs.), glaucous gulls and black guillemots (< 100 prs. each) - May to end of September.

S:Ed

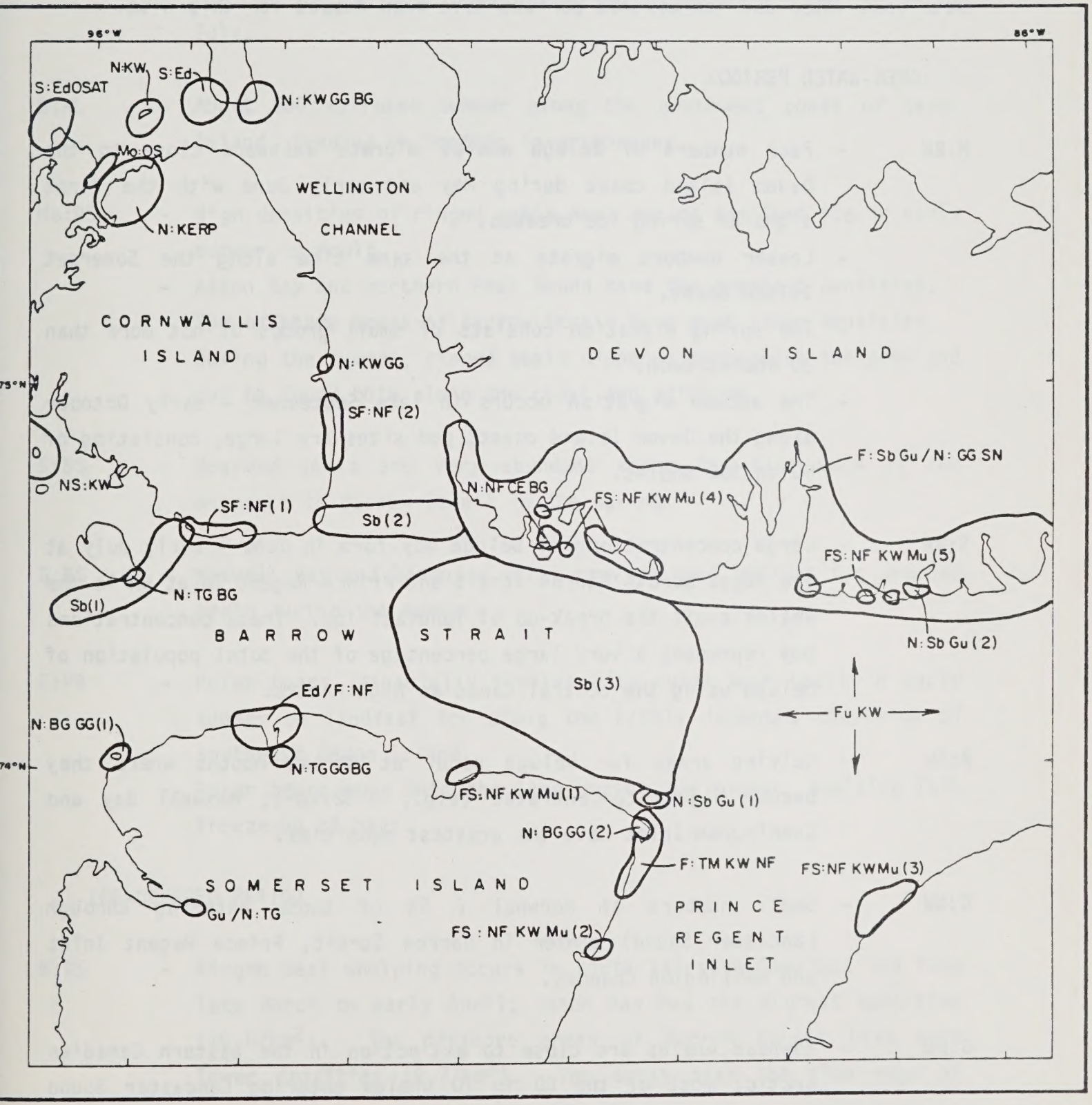
- Polynya - Baillie Hamilton Island. Spring staging area for eiders.

GENERAL

This region represents an important nesting and feeding area for a variety of seabirds and waterfowl. Summer concentrations around colonies and over offshore areas are variable but generally high relative to other regions in the Arctic. In many cases (e.g., murres) a significant proportion of the world's population breeds in the region.

Concentrations of birds are seen as soon as leads begin to open in the early spring and most species remain until mid or late September.

SEABIRDS



SITE 7 : CAPE LIDDON
OPEN-WATER PERIOD

FIG. B.47

SITE 7: CAPE LIDDON

Both open-water and ice-covered periods have been mapped for this site.

OPEN-WATER PERIOD:

M:BW
- Peak numbers of beluga whales migrate westward close to the Devon Island coast during May and early June with the first signs of spring ice breakup.
- Lesser numbers migrate at the same time along the Somerset Island coast.
- The spring migration consists of small groups of not more than 20 whales each.
- The autumn migration occurs in late September - early October along the Devon Island coast; pod sizes are large, consisting of 80 to 300 whales.

S:BW
- Large concentrations of beluga may form in June - early July at ice edges across Barrow Strait and Prince Regent Inlet while the whales await the break-up of landfast ice. These concentrations may represent a very large percentage of the total population of beluga using the central Canadian high Arctic.

R:BW
- Calving areas for beluga occur at stream mouths where they become highly concentrated (e.g., > 32/km^2); Maxwell Bay and Cunningham Inlet have the greatest densities.

G:NW
- Small numbers of narwhal (5% of those entering through Lancaster Sound) summer in Barrow Strait, Prince Regent Inlet and Wellington Channel.

G:BH
- Bowhead whales are close to extinction in the eastern Canadian Arctic; most of the 60 to 70 whales entering Lancaster Sound continue westward into Barrow Strait, Wellington Channel, and

Prince Regent Inlet. Areas of concentration have not been observed.

M:WL - About 500 walruses move westward along the Devon Island coast in the spring, with a peak occurring from early June to early July.

G:WL - About 300 walruses summer along the southwest coast of Devon Island, feeding on benthic invertebrates.

Mo:RS - High densities of ringed seals haul out on landfast ice in early summer to moult.
- Aston Bay and northern Peel Sound have the greatest densities.
- The offshore areas of Barrow Strait have much lower densities.
- During the summer, ringed seals disperse throughout the area and can be found both along the coast and offshore.

S:BS - Bearded seals are very abundant along the floe edge of the entrance to Barrow Strait in the spring.

G:BS - Maxwell Bay and Gascoyne Inlet provide good habitat for bearded seals during the summer.

F:PB - Polar bears (especially females with cubs) hunt seals in early summer on landfast ice along the highly indented coastline of southwest Devon Island.
- Polar bears move onto the land during the summer, awaiting fall freeze-up of bays.

ICE-COVERED PERIOD

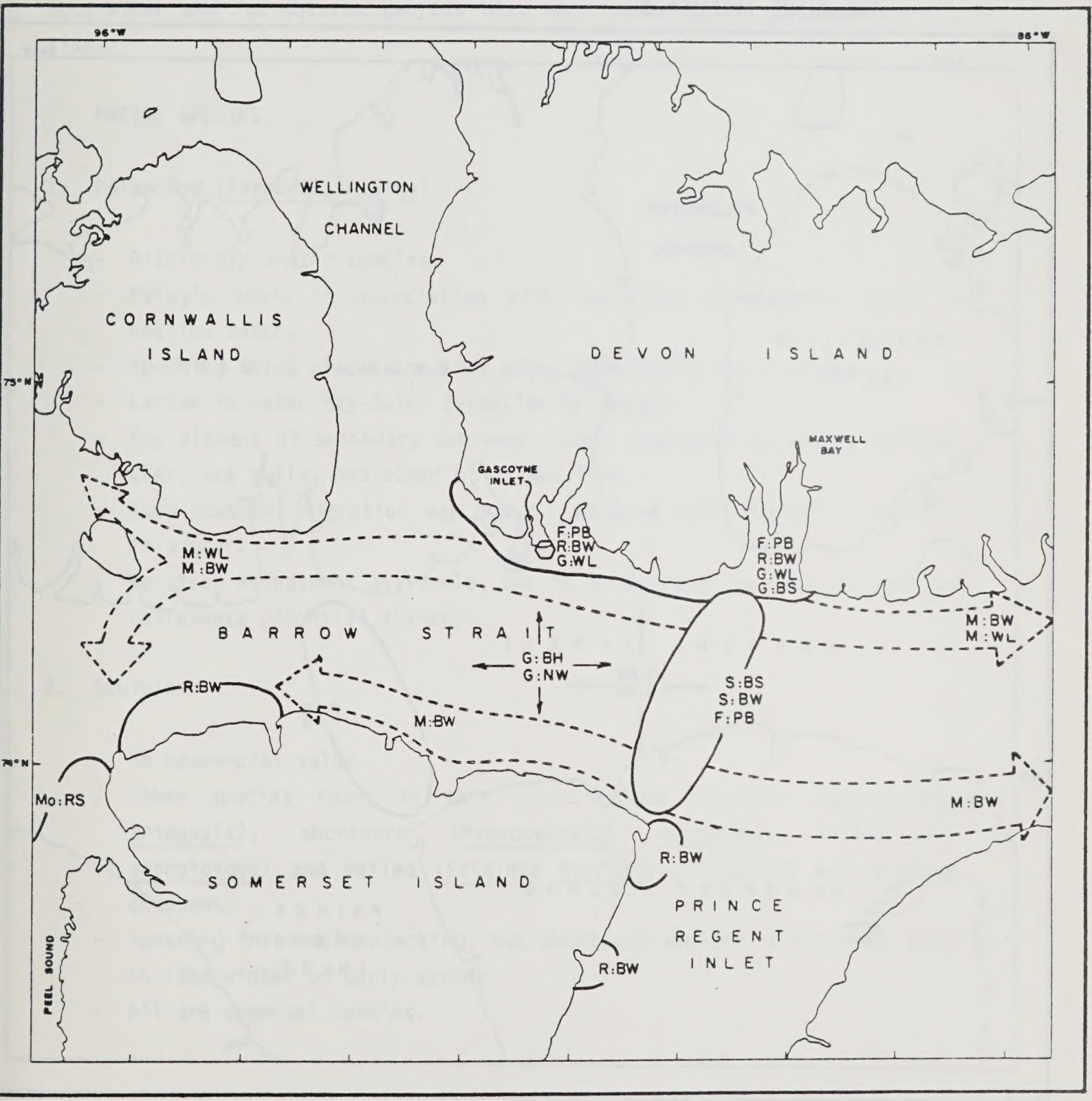
R:RS - Ringed seal whelping occurs in birth lairs on landfast ice from late March to early April; Aston Bay has the highest densities (10.0/km^2). The offshore areas of Barrow Strait have much lower densities (0.7/km^2). The areas near the floe edge at

the mouth of the Barrow Strait also has high densities of birth lairs.

G:PB - Polar bears are dispersed over the ice in Barrow Strait during the winter.

F:PB - Polar bears prefer to hunt seals along ice edges and thus concentrate along the ice edge at the mouth of Barrow Strait.

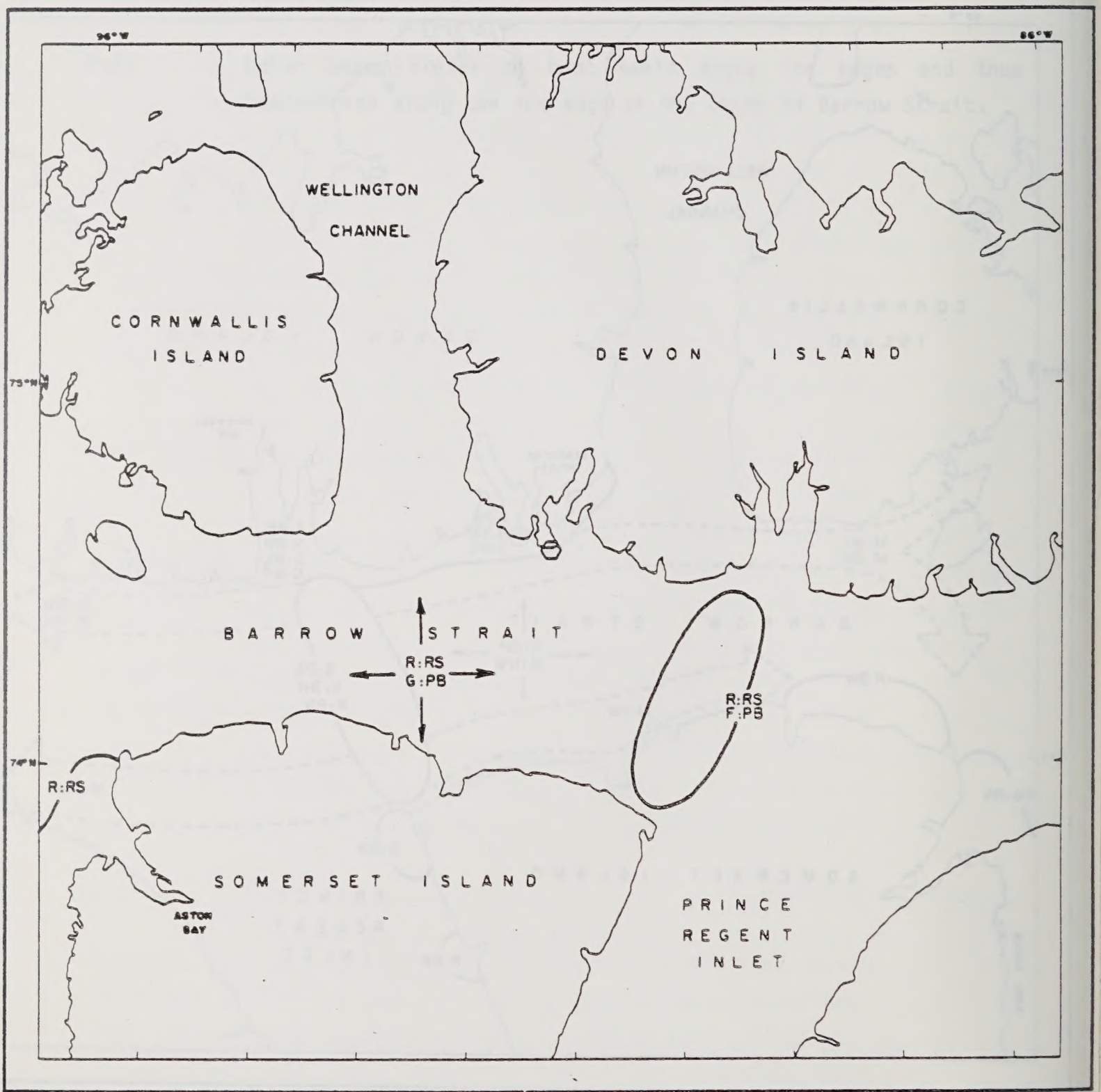
MARINE MAMMALS



SITE 7 : CAPE LIDDON
OPEN - WATER PERIOD

FIG. B.48

MARINE MAMMALS



SITE 7 : CAPE LIDDON
ICE - COVERED PERIOD

FIG. B.49

SITE 7: CAPE LIDDON

Open-water and ice-covered periods have been combined in one map for this site.

MARINE SPECIES

1. Polar Cod (Boreogadus saida)

- Distinctly arctic species.
- Pelagic habit in association with ice floes or demersal habit in shallow water.
- Spawning takes place along ice edge, principally early winter.
- Larvae in water May-July; juveniles by August.
- Key element of secondary consumer level, preyed on by seals, belugas, char, sea gulls, and other birds and fish.
- Some seasonal migration may occur - inshore fall migration, offshore in summer.
- No stock assessment available, but it is known to be very abundant and represents potential fishery.

2. Sculpins

- No commercial value.
- Other species found in this area include staghorn (Gymnocanthus tricuspis), shorthorn (Myoxocephalus scorpius), Arctic (M. scorpioides) and mailed (Triglops murrayi). Fourhorn and staghorn abundant.
- Spawning information lacking, but shorthorn sculpin is known to spawn in late winter or early spring.
- All are demersal species.

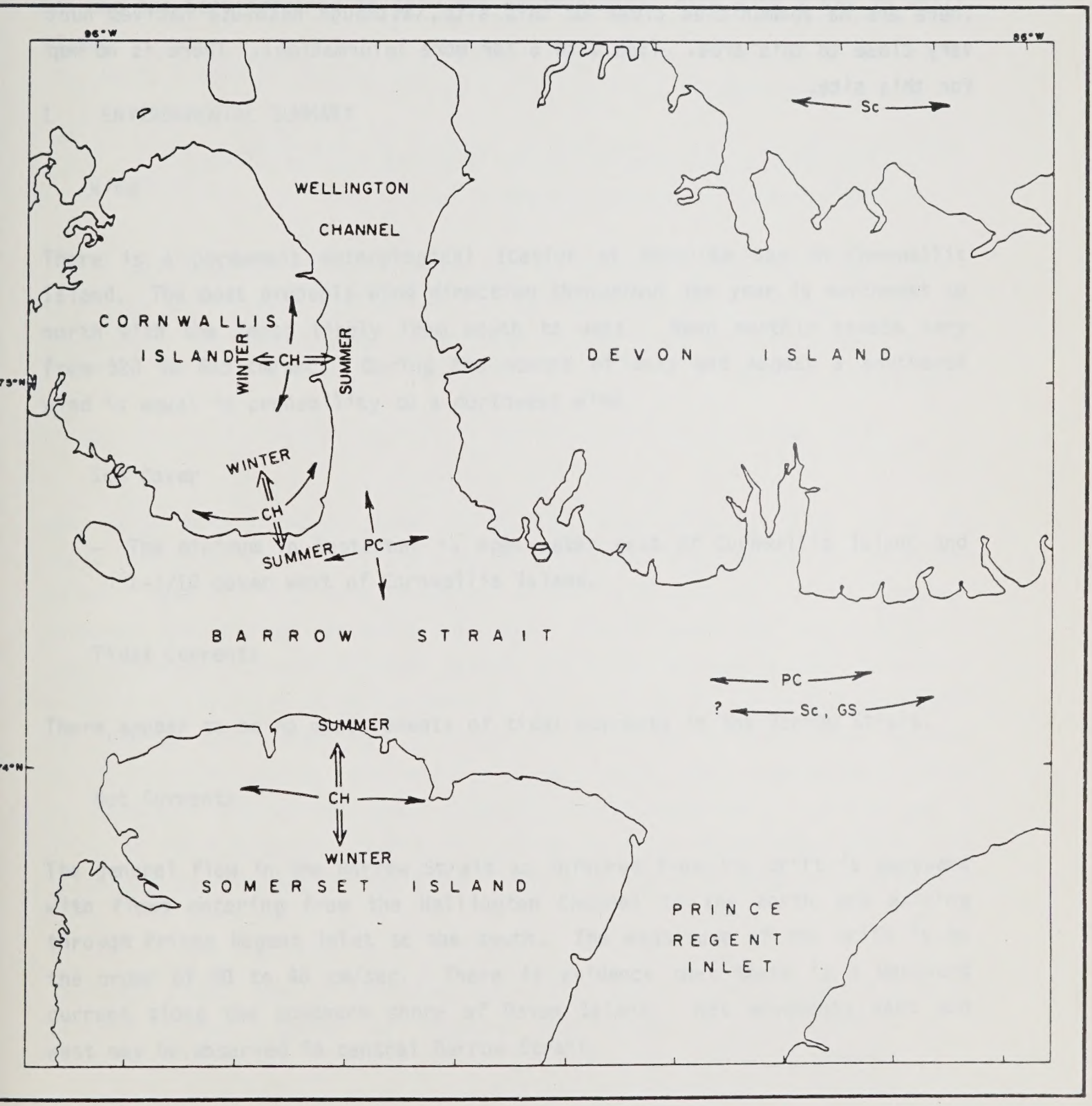
3. Greenland Shark (Somniosus microcephalus)

- Found near surface or along coasts during winter (often along ice edge).
- Moves to deeper water (200 m) during summer.
- Opportunistic feeder, but relies heavily on carrion, seals.

4. Arctic Char (Salvelinus alpinus)

- Runs to sea in spring to feed.
- Returns to rivers and streams in late summer/fall to spawn.
- Slow growing fish.
- Eggs incubate overwinter; smolts remain in rivers and lakes for 5-7 years before running to sea (150-200 mm length).
- Important food source for man, terns, loons, char and seals.
- Potential for increased fishery exists.

FISHERY RESOURCES



SITE 7 : CAPE LIDDON

FIG. B.50

SITE 7: CAPE LIDDON

There are no communities close to this site, although Resolute natives hunt very close to this area. (See Site 6 for more information). There is no map for this site.

HYPOTHETICAL SLICK MOVEMENT

SITE 7: CAPE LIDDON

One map has been prepared to show the environmental data with a key to spill sizes.

I ENVIRONMENTAL SUMMARY

Wind

There is a permanent meterological station at Resolute Bay on Cornwallis Island. The most probable wind direction throughout the year is northwest to north with the least likely from south to west. Mean monthly speeds vary from 520 to 615 cm/sec. During the months of July and August a southeast wind is equal in probability to a northwest wind.

Ice Cover

- The minimum in September is open water east of Cornwallis Island and 1-3/10 cover west of Cornwallis Island.

Tidal Currents

There appear to be no measurements of tidal currents in the Barrow Strait.

Net Currents

The general flow in the Barrow Strait as inferred from ice drift is eastward with flows entering from the Wellington Channel to the north and exiting through Prince Regent Inlet to the south. The magnitude of the drift is on the order of 20 to 40 cm/sec. There is evidence that there is a Westward current along the southern shore of Devon Island. Net movements east and west may be observed in central Barrow Strait.

II SURFACE SLICK

General

This spill site is located off the south shore of Devon Island. In this case even a relatively small spill might impact quite a large area. This is due to two considerations:

1) The lack of reduction of volume by weathering before impact.
2) The geometry of spreading along a coast.

A small spill occurring directly off the coast might never leave the coast. For larger spills, a portion will likely move off the coast. The following discussions assume the spill occurs near the coast and does not immediately impact Devon Island.

Trajectory

If an oil spill were to move offshore it would probably move under the influence of the general eastward flow and the prevailing Northwest wind. However, it is also possible that a Southeast wind and the west flowing currents along the shore could cause the slick to go in the opposite direction. Either east or south the nearest landfall is approximately 60 km. Assuming a net drift of 15 km/day due to wind and 30 km/day currents gives a maximum drift velocity of 45 km/day which is consistent with maximum ice drift observations. This gives a minimum travel time to land on the order of a day or two. The most likely landfall would be to the southeast at approximately 160 km or on the order of 3 or 4 days. Judging from ice drift information it seems feasible that the slick might go due east out Lancaster Sound.

30 m^3 - Surface extent is small in scale relative to open water features. Significant in scale with respect to nearby smaller coastal features.

300 m^3 - Significant in scale relative to coastal features.

3,000 m^3 - Substantial with respect to coastal features, significant relative to open water.

30,000 m^3 - Significant in scale even in open water as maximum spread approaches dimensions of Strait.

III WATER COLUMN CONCENTRATIONS

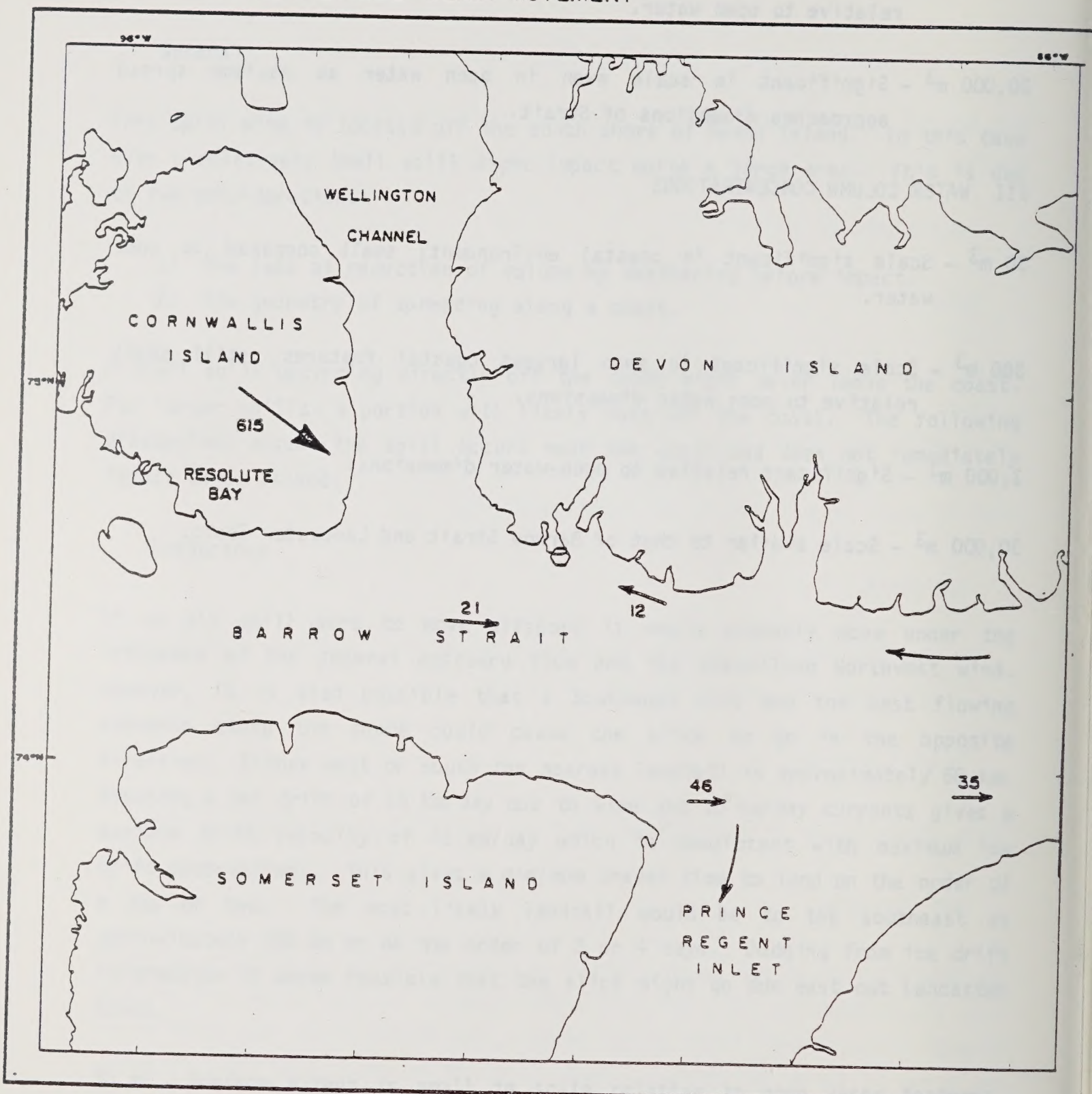
30 m^3 - Scale significant in coastal environment; small compared to open water.

300 m^3 - Scale significant in even largest coastal features, still small relative to open water dimensions.

3,000 m^3 - Significant relative to open-water dimensions.

30,000 m^3 - Scale similar to that of Barrow Strait and Lancaster Sound.

HYPOTHETICAL SLICK MOVEMENT



SITE 7 : CAPE LIDDON

Spill Volume
30 m^3
300 m^3
3000 m^3
30000 m^3

Slick Diameter
1.8 km
5.6 km
18 km
45 km

Diameter 100 ppb Contamination
4.1 km
13.0 km
41 km
130 km

FIG. B.51

SITE 8: CAPE HAY

Both open-water and ice-covered information have been mapped.

Lancaster Sound has a longer open water period than surrounding waters and is considered a spring polynya.

Pp
- Lancaster Sound is highly productive; up to 10 times other Arctic areas (e.g., Beaufort Sea).
- Epontic bloom occurs from late April to early June.
- Planktonic algal bloom occurs from July to mid-September.
- Top 5 m are impoverished due to temperature/salinity variability.
- Macrophytes are important in shallow water areas.

Zb
- Epontic community is well developed; dominated by benthic amphipods.
- Copepods dominate open water zooplankton in numbers and biomass.
- Greatest concentration occurs at a depth of 50 m.
- Pteropods are important plankters in mid-sound waters.

Zb
- Benthic communities are well developed with biomass equivalent to boreal and temperate waters.
- Highest biomass occurs in shallow waters, bays and inlets.
- Bivalves are important infauna; up to 400 g/m^2 fresh weight.
- Diverse epifauna and macrophyte communities are present on hard substrate.
- Barren zone from 0-5 m.

PLANKTON / INVERTEBRATES

SITE 8 : CAPE HA
OPEN - WATER PERIO

FIG. B.52

SEABIRDS

SITE 8: CAPE HAY

Both open-water and ice-covered periods have been mapped for this site.

OPEN-WATER PERIOD

FN:Sb

- Lancaster Sound - Cape Horne to Wellington Channel. Feeding areas for northern fulmars, black guillemots, glaucous gulls, thick-billed murres, black-legged kittiwakes. Scattered colonies of glaucous gulls (10-30 prs. each) and inland colonies of greater snow geese - May to October.

FNMo:Sb

- Cape Horne, and Croker Bay to Philpots Island - Devon Island. "Most critical to production and survival of a large proportion of the total seabird populations in the Canadian High Arctic". Major feeding area for 5 northern fulmar colonies (156,000 prs.), breeding thick-billed murres (600,000 prs.) and black-legged kittiwakes (60,000 breeding prs.). Heavily used by Greenland dovekies in May. Also present are glaucous, Thayer's, and ivory gulls. Greater snow geese breed east of Croker Bay and moult in the area. Croker Bay and Dundas Harbour also important area for moulting common eider males.

SN/N:AB

- Philpots Island - Important breeding area for Atlantic brant. Greater snow geese also present.

Sb(1)

- Moderate pelagic concentrations of seabirds, September and October.

N:NF/F:Sb

- Baillarge Bay - Baffin Island. Large nesting area for northern gulls, black-legged kittiwakes, thick-billed murres, black guillemots, greater snow geese, oldsquaws and eiders.

FuKWTMEd

- North Borden Peninsula and Bylot Island. Dense concentrations of fulmars, black-legged kittiwakes and thick-billed murres occur May to August (up to 700 birds/km^2). Common and king eiders concentrate along the southern shore of the Sound - late May to early June (ca. 20,000 individuals).

Mf:TM

- Fall migratory route thick-billed murres (300,000 individuals).

N:KW

- Wollaston Island. Nesting area for black-legged kittiwakes (100-1000 individuals).

N:Sb

- West of Cape Hay - Bylot Island. Large nesting area for black-legged kittiwakes (ca. 20,000 prs.)., thick-billed murres (140,000 prs.). Nesting by glaucous gulls (ca. 100 prs.), Thayer's gulls, black guillemots (ca. 100 prs.) - May to end September.

FuKW

- Central Lancaster Sound - Large numbers of fulmars and kittiwakes although not as great as nearshore.

FS:DV

- Eastern Lancaster Sound - Baffin Bay. Dense concentration of dovekies (1,500,000 estimated in May, 1976). Feeding grounds in May for almost all western Greenland population of dovekies.

Sb(2)

- Moderate pelagic concentrations - July and August.

N:KWTM

- Cape Graham Moore - Bylot Island. Nesting area for black-legged kittiwakes (ca 3000 prs.), thick-billed murres (ca. 20,000 prs.) May to end September.

N:GuBGATSN

- Bylot Island Migratory Bird Sanctuary (entire island). Breeding area for glaucous gulls, Thayer's gulls, Sabine's gulls, black guillemots, Arctic terns. Colonies of greater snow geese in southwest.

MuFuKW

- Eclipse Sound. Large pelagic concentrations of murres, fulmars, kittiwakes, etc.

N:WfSh

- Southwest portion of Bylot Island. Nesting area for shore-birds, greater snow geese (7500 prs.), red-throated loons, oldsquaws, king eiders, Atlantic brant.

S:SN

- Eclipse Sound. Heavily used pre-migratory staging area for greater snow geese - August.

ICE-COVERED PERIOD

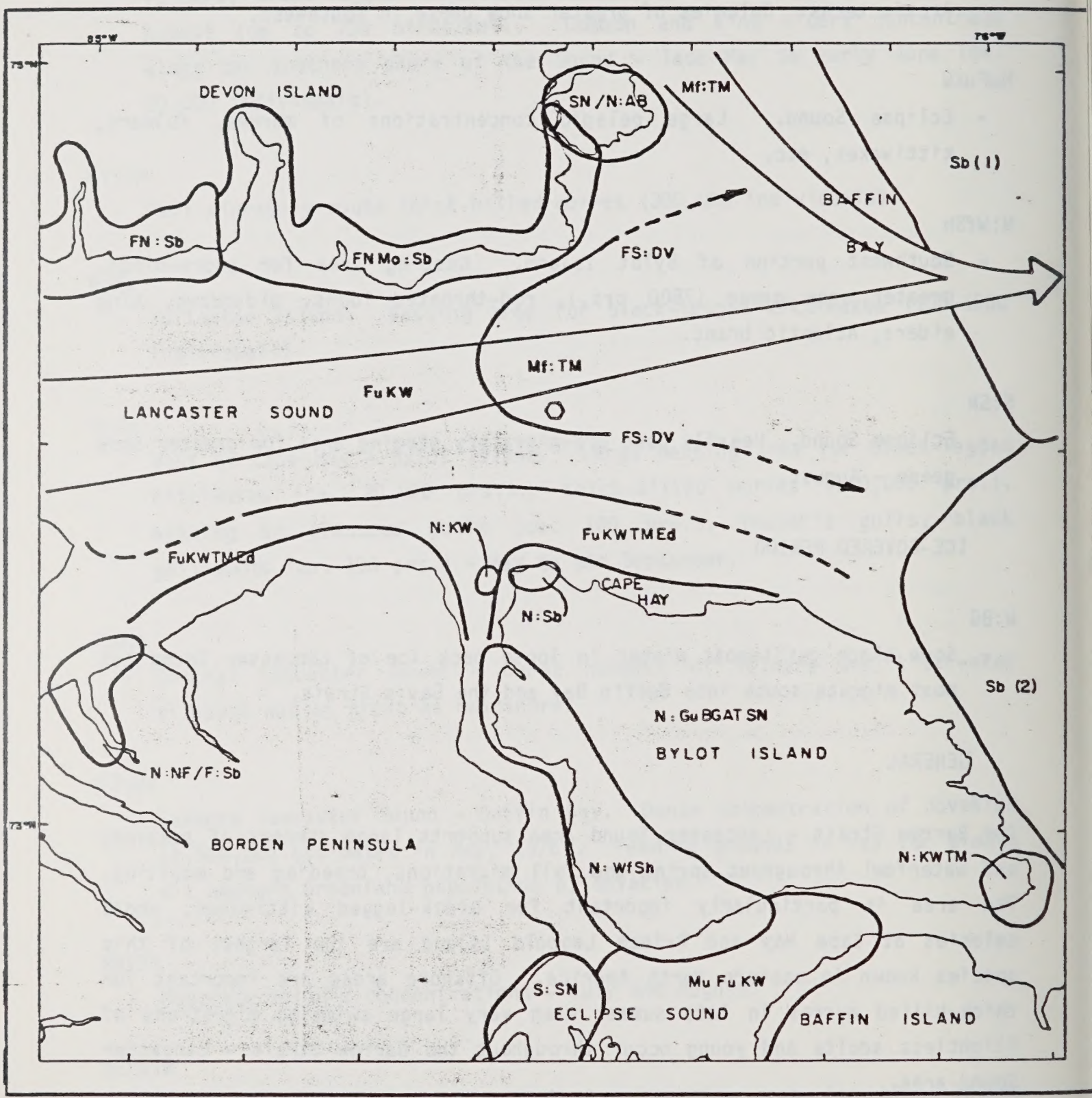
W:BG

- Some black guillemots winter in loose pack ice of Lancaster Sound but most migrate south into Baffin Bay and the Davis Strait.

GENERAL

The Barrow Strait - Lancaster Sound area supports large numbers of seabirds and waterfowl throughout spring and fall migrations, breeding and moulting. The area is particularly important for black-legged kittiwakes, whose colonies at Cape Hay and Prince Leopold Island are the largest of this species known in eastern North America. Offshore areas are important for thick-billed murres in late summer when very large swimming migrations of flightless adults and young occur throughout the Barrow Strait - Lancaster Sound area.

SEABIRDS



SITE 8 : CAPE HAY
OPEN - WATER PERIOD

FIG. B.53

MARINE MAMMALS

SITE 8: CAPE HAY

Both open-water and ice-covered periods have been mapped for this site.

OPEN-WATER PERIOD:

Ms:BW
- Large numbers of beluga whales (6,000 - 10,000) migrate westwards along the shore lead south of the Devon Island coast during spring breakup in May.
- Large numbers of beluga (2,000 - 5,000) migrate westwards along the Bylot Island coastal somewhat later in June.
- Spring migration extends over 3 to 4 months (mid-March to end of June) with animals well dispersed in groups of 20 whales.

Mf:BW
- Peak numbers of beluga whales (10,000 - 15,000) migrate eastwards along the Devon Island shore (within 30 m) during last half of September. Smaller numbers follow the Bylot Island coast.
- Croker Bay, C. Warrender and Bethune Inlet are brief staging areas during migration.

Ms:NW
- Numbers of narwhal migrating through Sound not known.
- Large numbers of narwhal migrate westwards through Lancaster Sound from mid-June to the end of July. Total Eastern Arctic population estimates are rough; 20,000 - 30,000 narwhal. Densities are greatest in late July along the ice edges of Admiralty and Navy Board Inlets (25/km^2 and 54/km^2 respectively) where narwhal accumulate while waiting to move into these inlets as soon as the ice disappears.
- Offshore waters have a lower density: 0.5/km^2 during the spring migration.
- Herds are usually small (< 25 animals) during the spring migration.

R:NW
- Estimates range from 5,000 - 12,000 narwhal summering in Eclipse Sound Complex and Admiralty Inlet.
- Milne Inlet is a calving area for several thousand narwhal.
- These consist predominatly of females and calves; larger males continue to move westward to summer in Barrow Strait, Prince Regent Inlet and Peel Sound.

Mf:NW
- The peak of the autumn migration of narwhal eastwards through Lancaster Sound occurs in late September; herds are usually large (several hundred animals).
- Densities are greatest along the coast, especially the Devon Island coast (4.5/km^2).

Ms:WL
- About 500 walruses move westward along the Devon Island coast during July en route to the Bathurst Island summering area.

G:WL
- An unknown number of walruses summer along the shores of Lancaster Sound from early June to early October with highest densities in Croker Bay and south of Philpots Island (3-4/km^2).
- Haulout sites:
  1. Dundas Harbour - numbers unknown.
  2. Southeast Philpots Island - numbers unknown.
  3. Wollaston Island - 200 - 300.

Mf:WL
- Autumn migration of central high arctic summering population (500 walruses) occurs along the Devon Island coast during late September - early October.

M:BH
- Bowhead whales are close to extinction in the eastern Canadian Arctic, with about 60-70 whales passing east- wards through Lancaster Sound during late June - early July.
- A summer feeding area has not been identified.
- Autumn migration probably occurs in October.

Mo:BS - Bearded seals haul-out on offshore ice floes during moult in May and June.
- Numbers are unknown (< 100 observed during 7-1/2 month census).

G:BS - Bearded seals are usually dispersed but concentrate coastally in September, especially at Croker Bay.

Mo:RS - Ringed seals are very abundant (total population unknown) during the summer period; high densities occur at Croker Bay, southeast Philpots Island and Navy Board Inlet where they haul out on landfast ice to moult in May and June. Moulting also occurs on offshore ice.

F:PB - Polar bears concentrate along the ice edge of the mouths of Navy Board Inlet, Admiralty Inlet, and Croker Bay in the spring, where they feed on seals.
- They retreat to the land during the summer.

F:HS - Large numbers of harp seals enter Lancaster Sound in July to feed along the coast and at ice edges across inlets.

G:HS - Harp seals may be found offshore when the ice disappears.

ICE-COVERED PERIOD:

G:RS - Adolescent and adult ringed seals use the open leads near the floe edge from mid-October to mid-May.

G:PB - Polar bears concentrate in these areas from mid-October to mid-May. They represent important feeding areas during the winter.

R:BS - Bearded seals may pup in the offshore areas of Lancaster Sound in late April. Bearded seals do not maintain breathing holes in fast ice - therefore they may use the open leads near the edge of the pack ice during winter.

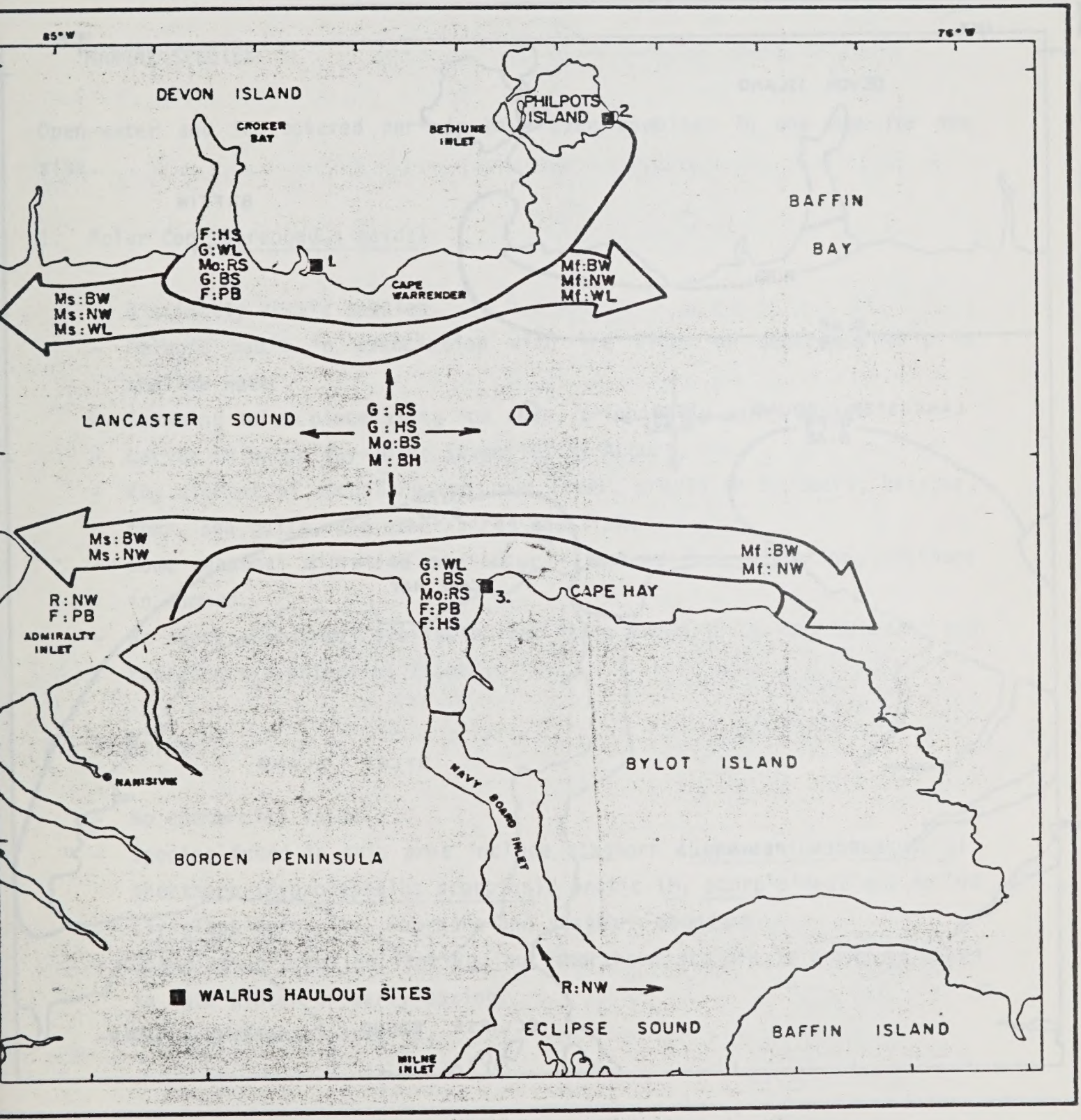
- It is possible that bearded seals leave the Sound during the winter.

G:AF - The open leads near the edge of the pack ice may be an important scavenging area for Arctic fox. The inshore landfast area may also be used.

S:BW - Small numbers of beluga whales can arrive at southeast Devon Island as early as mid-March, and extend westwards along the shore lead during April.

R:RS - Ringed seals pup on landfast ice during late March - early April.

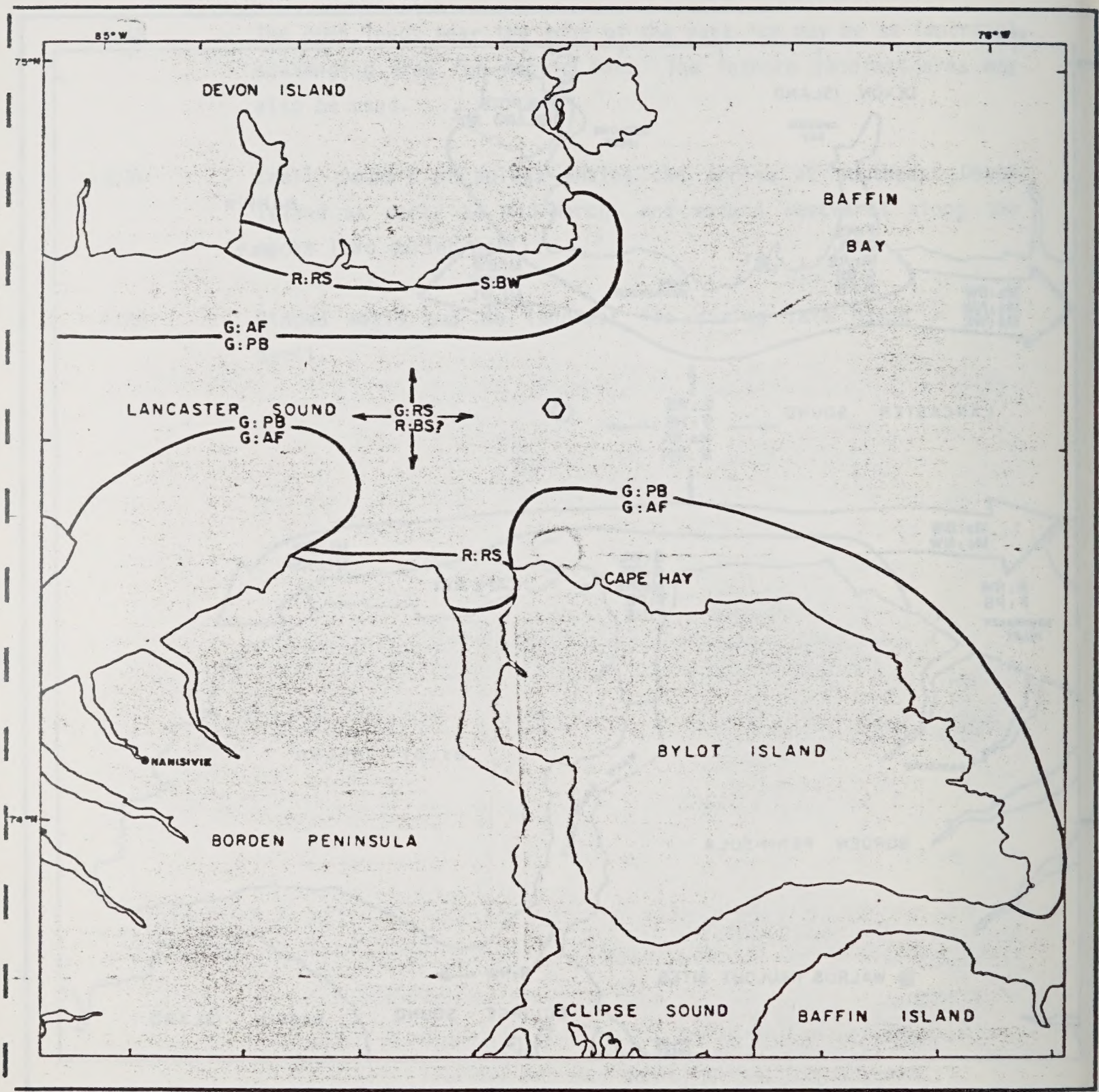
MARINE MAMMALS



SITE 8 : CAPE HAY
OPEN-WATER PERIOD

FIG. B.55

MARINE MAMMALS



SITE 8 : CAPE HAY
ICE-COVERED PERIO

FIG. B.56

FISHERY RESOURCES

SITE 8: CAP HAY

MARINE SPECIES

Open-water and ice-covered periods have been combined in one map for the site.

1. Polar Cod (Boreogadus saida)

- Distinctly arctic species.
- Pelagic habit in association with ice floes or demersal habit in shallow water.
- Spawning takes place along ice edge, principally early winter.
- Larvae in water May-July; juveniles by August.
- Key element of secondary consumer level, preyed on by seals, belugas, char, sea gulls, and other birds and fish.
- Some seasonal migration may occur - inshore fall migration, offshore in summer.
- No stock assessment available, but it is known to be very abundant and represents a potential fishery.

2. Sculpins

- No commercial value.
- Species found in this area include staghorn (Gymnocanthus tricuspis), shorthorn (Myoxocephalus scorpius), Arctic (M. scorpioides) and mailed (Triglops murrayi). Fourhorn and staghorn abundant.
- Spawning information lacking, but shorthorn sculpin is known to spawn in late winter or early spring.
- All are demersal species.

3. Greenland Shark (Somniosus microcephalus)

- Found near surface or along coasts during winter (often along ice edge).
- Moves to deeper water (200 m) during summer.
- Opportunistic feeder, but relies heavily on carrion, seals, halibut and salmon.
- Represents potential fishery (primarily for its oil).

4. Greenland Halibut (Reinhardtius hippoglossoides)

- Deep water species.
- Does not spawn here.
- Distribution and abundance unknown in this area.

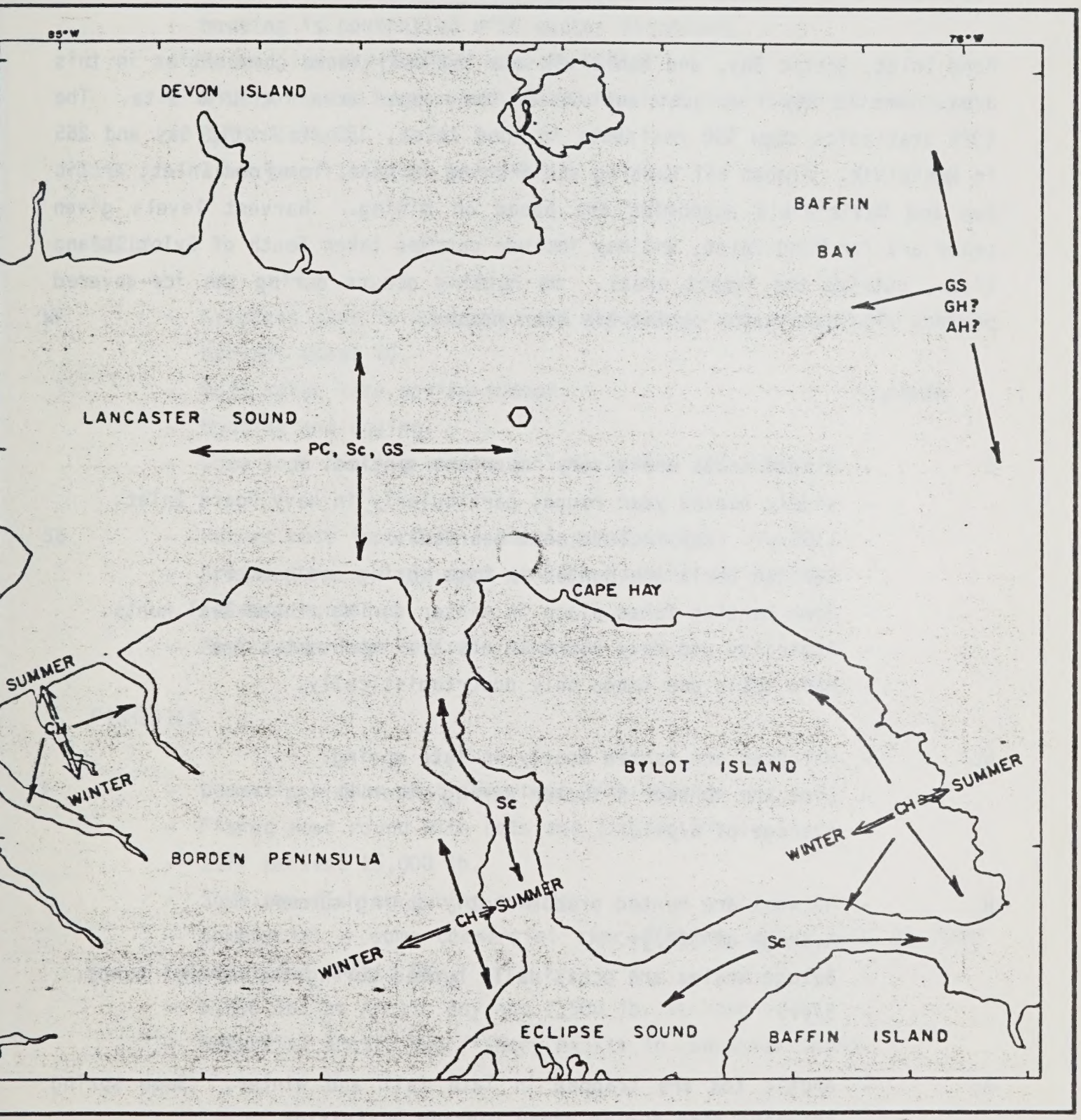
5. Atlantic Halibut (Hippoglossus hippoglossus)

- Exhibits inshore/offshore seasonal migrations.
- Distribution and abundance unknown for this site.
- Spawning information limited; possibly spring or summer. Juveniles move offshore as they develop.
- May be a potential fishery species although stocks are probably low here.

6. Arctic Char (Salvelinus alpinus)

- Runs to sea in spring to feed.
- Returns to rivers and streams in late summer/fall to spawn.
- Slow growing fish.
- Eggs incubate overwinter; smolts remain in rivers and lakes for 5-7 years before running to sea (150-200 mm length).
- Important food source for man, terns, loons, char and seals.
- Most important domestic and commercial fish species in this area.
- Potential for increased fishery exists.

FISHERY RESOURCES



SITE 8 : CAPE HAY

FIG. B. 57

SITE 8: CAPE HAY

Pond Inlet, Arctic Bay, and Nanisivik are the only three communities in this area. Arctic Bay lies just outisde of the mapped area for this site. The 1978 statistics show 550 residents in Pond Inlet, 353 in Arctic Bay and 265 in Nanisivik. Almost all hunting and fishing is done from Pond Inlet; Arctic Bay and Navisivik's economies are based on mining. Harvest levels given below are for Pond Inlet, and may include catches taken South of Bylot Island (i.e., outside the impact area). No hunting occurs during the ice-covered period. The open-water period has been mapped.

MAMMALS

S
- Ringed seals are a very important species.
- Widely hunted year round, particularly in Navy Board Inlet.
- 1355/yr. (may include some bearded).
- Bearded seals are hunted in late spring and summer.
- Some hunting takes place in winter during ringed seal hunts.
- Admiralty and Navy Board Inlets are important sites.
- Harp seals are taken only opportunistically.

WL
- Walruses are hunted mostly in late spring.
- Some are hunted in summer during other hunts.
- Average of 6/yr.

W
- Narwhal are hunted predominantly during summer.
- Average of 125/yr.
- Beluga whales are occasinally hunted during the narwhal hunts.
- 5/yr.

AF
- Arctic fox are trapped in late fall and winter. Some spring trapping done during other hunting activities.
- A few coloured foxes taken also.
- Average 178 Arctic and 3 coloured taken per year.

- Entire coastline of north Baffin Island hunted.

PB
- Polar bears are a very important species to Inuit hunters; hunting is controlled with quotas allocated.
- Hunted January to May; some in fall.
- Widely hunted over north Baffin island and southeast coast of Bylot Island.
- Average of 11 taken per year.

BIRDS

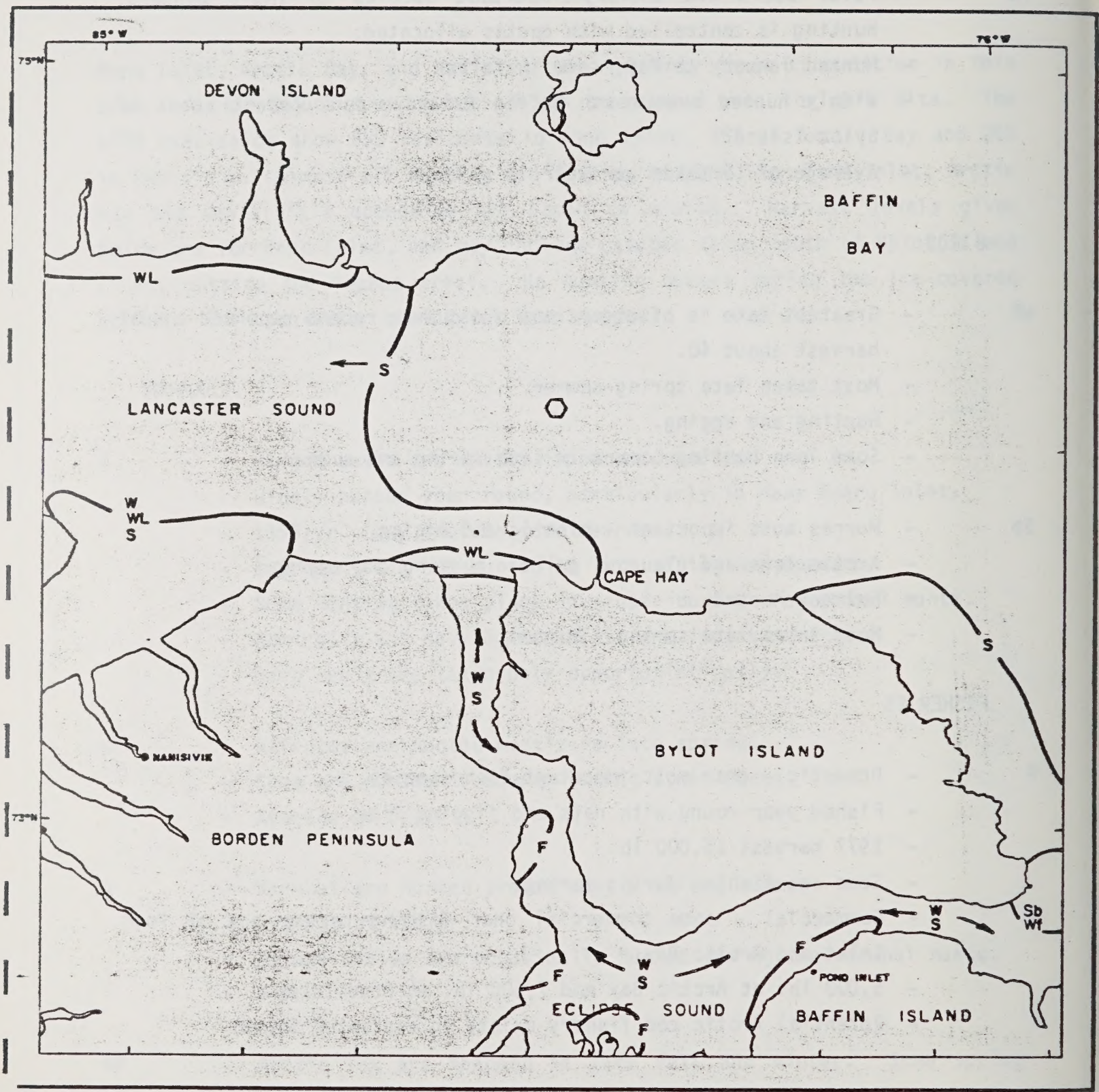
WF
- Greatest take is of eiders and oldsquaws; recent reported annual harvest about 40.
- Most taken late spring-summer.
- Hunting and egging.
- Some loon hunting occurs in late spring and summer.

Sb
- Murres most important - hunting and egging.
- Arctic tern and glaucous gulls - hunting and egging.
- Fulmars hunted.
- Most taken late spring - summer.

FISHERIES

F
- Domestic - char most important fish species.
- Fished year round with nets and jigging line.
- 1977 harvest 15,000 lb.
- Some sea fishing during spring.
- Commercial - some commercial char fishing occurs out of Pond Inlet and Arctic Bay.
- 5,000 lb. at Arctic Bay and 7,500 lb. at Pond Inlet.
- Potential Arctic cod fishery exists in Lancaster Sound.

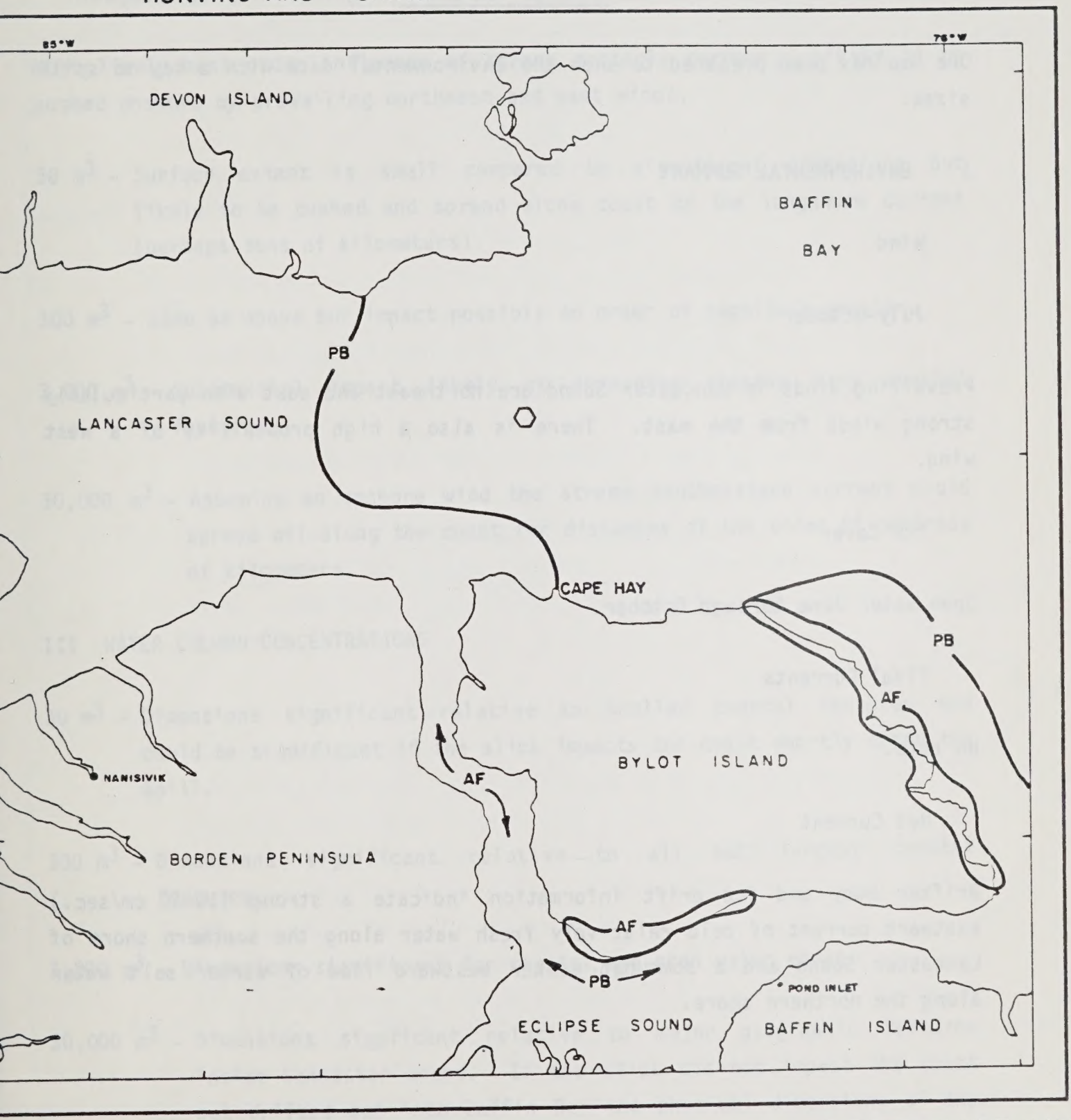
HUNTING AND FISHING



SITE 8 : CAPE HAY
OPEN-WATER PERIOD

FIG.B.58

HUNTING AND FISHING



SITE 8 : CAPE HAY
ICE - COVERED PERIOD

FIG. B.59

HYPOTHETICAL SLICK MOVEMENT

SITE 8: CAPE HAY

One map has been prepared to show the environmental data with a key to spill sizes.

I ENVIRONMENTAL SUMMARY

Wind

July-October

Prevailing winds in Lancaster Sound are northeast and east with particularly strong winds from the east. There is also a high probability of a west wind.

Ice Cover

Open water June through October.

Tidal Currents

No data.

Net Current

Drifter buoy and ice drift information indicate a strong (10-50 cm/sec.) eastward current of cold relatively fresh water along the southern shore of Lancaster Sound and a somewhat weaker westward flow of warmer salt water along the northern shore.

II SURFACE SLICK

Trajectory

Most likely east under influence of strong easterly current. Likely to be pushed onshore by prevailing northeast and east winds.

30 m^3 - Surface extent is small compared to significant dimensions but likely to be pushed and spread along coast by the longshore current (perhaps tens of kilometers).

300 m^3 - Same as above but impact possibly an order of magnitude greater.

3,000 m^3 - Substantial impact likely as spreading reaches many coastal features.

30,000 m^3 - Assuming an onshore wind the strong southeastern current could spread oil along the coast for distances of the order of hundreds of kilometers.

III WATER COLUMN CONCENTRATIONS

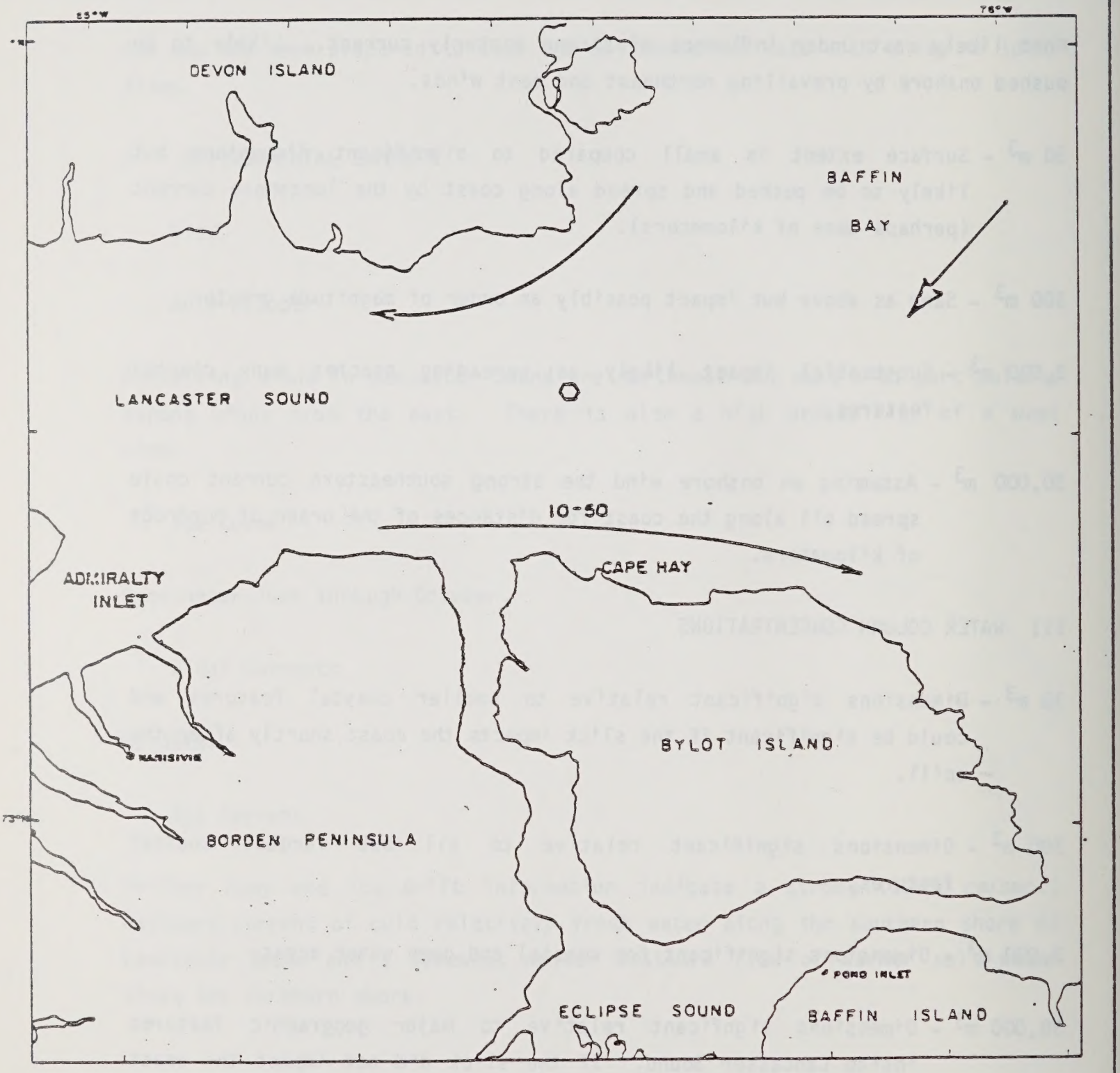
30 m^3 - Dimensions significant relative to smaller coastal features and could be significant if the slick impacts the coast shortly after the spill.

300 m^3 - Dimensions significant relative to all but largest coastal features.

3,000 m^3 - Dimensions significant for coastal and open water areas.

30,000 m^3 - Dimensions signficant relative to major geographic features inside Lancaster Sound. If the slick did not impact the coast but drifted out into Baffin Bay the physical dimensions of the contaminated body of water would be relatively less significant.

HYPOTHETICAL SLICK MOVEMENT



SITE 8 : CAPE HAY

Spill Volume
30 m^3
300 m^3
3000 m^3
30000 m^3

Slick Diameter
1.8 km
5.6 km
18 km
45 km

Diameter 100 ppb Contamination
4.1 km
13.0 km
41 km
130 km

FIG. B.60

PLANKTON/INVERTEBRATES

SITE 9: CAPE HARRISON

Only the open-water period has been mapped; information for the ice-covered period is limited.

The pack ice retreats northwards, and is gone from the site by May or June. Landfast ice persists through June.

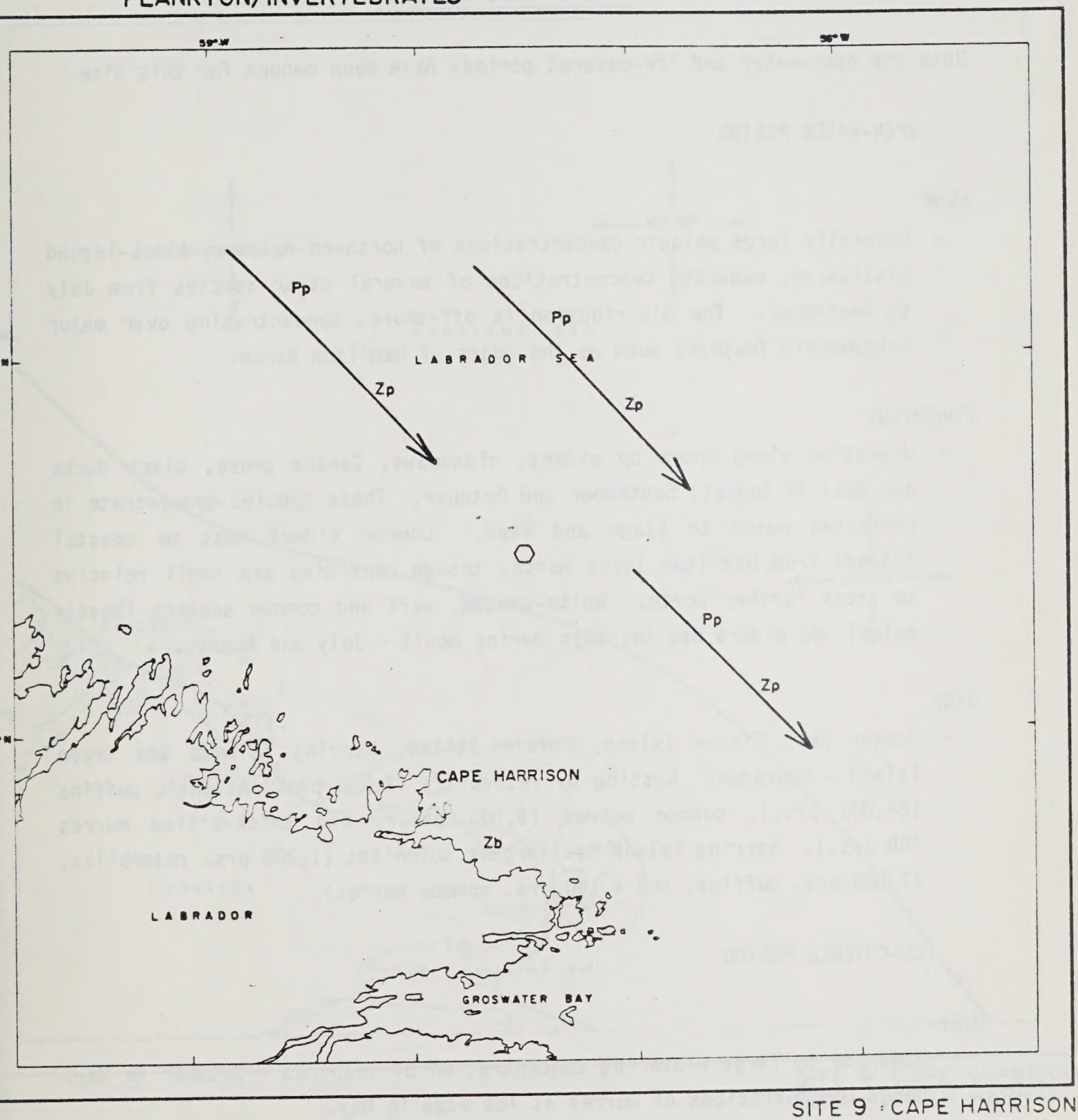
Pp
- Limited primary production data base for map area.
- Little specific information.
- Epontic flora evident under pack ice in March; peak in April.
- Epontic production more significant under fast ice, may persist until June.
- Phytoplankton bloom follows retreat of pack ice edge.
- Major peak late May/early June, secondary peak in August.
- Nearshore bloom dependent on break-up of fast ice.
- Higher production levels offshore.
- Tidal runs have high production/biomass, more senitive and important to region.

Zp
- Epontic faunal assemblage distinct from open water community.
- Epontic and open-water faunas temporally separate.
- Offshore open-water fauna dominated by Calanus finmarchicus.
- Calanus overwinters in deep water (> 100 m).
- Reproduction and larval stages timed to coincide with phytoplankton bloom; breeds in surface waters.
- One reproductive cycle per year.
- Major food source for higher trophic levels.
- Planktonic larvae of benthic species present in surface waters from June to September.

Zb
- Diversity and biomass of nearshore benthos affected by wave exposure and ice scour.

- Moderately sheltered shores show substantial perennial communities.
- Development of littoral communities in sheltered areas.
- Offshore benthos community composition controlled by substrate.
- Bivalve infauna dominates soft substrates.
- Biomass and diversity comparable to temperate waters.
- Productivity reduced due to low water temperature.

PLANKTON/INVERTEBRATES



SITE 9 : CAPE HARRISON
OPEN - WATER PERIOD

FIG. B.61

SEABIRDS

SITE 9: CAPE HARRISON

Both the open-water and ice-covered periods have been mapped for this site.

OPEN-WATER PERIOD

KWNF

- Generally large pelagic concentrations of northern fulmars, black-legged kittiwakes, moderate concentrations of several other species from July to September. The distribution is off-shore, concentrating over major bathymetric features such as the edges of Hamilton Banks.

FMoSMf:Wf

- Migration along shore by eiders, oldsquaws, Canada geese, black ducks and teal in August, September and October. These species concentrate in protected water to stage and feed. Common eiders nest on coastal islands from Hamilton Inlet north, though densities are small relative to areas further north. White-winged, surf and common scoters (mostly males) and eiders use the bays during moult - July and August.

N:Sb

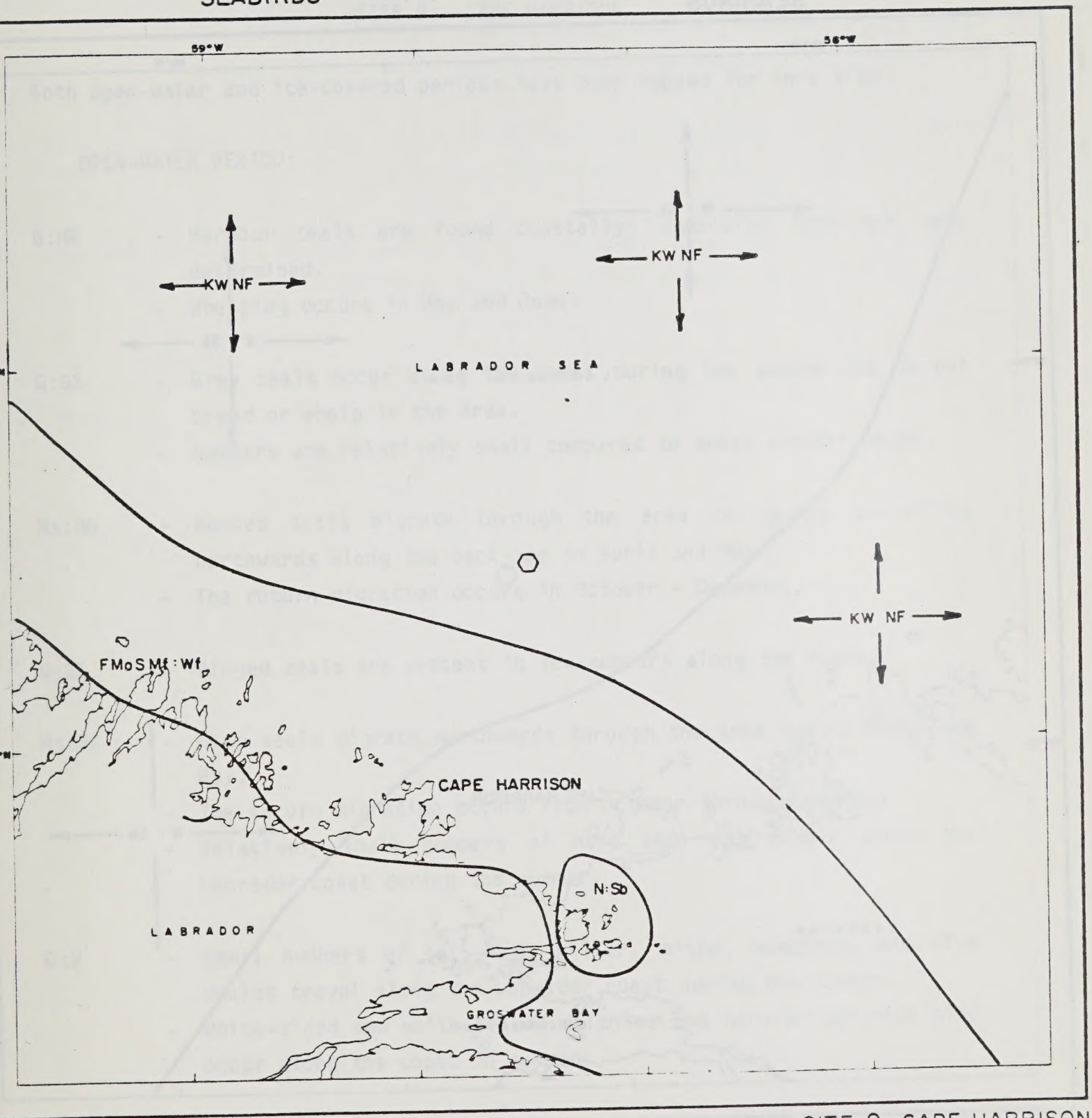
- Quaker Hat, Tinker Island, Puffin Island, Herring Islands and Green Island - Labrador. Nesting by razorbills (2,200 prs.) Atlantic puffins (24,000 prs.), common murres (5,000 prs.), and thick-billed murres 400 prs.). Herring Island has largest colonies: (1,200 prs. razorbills, 17,000 prs. puffins, and 4,100 prs. common murres).

ICE-COVERED PERIOD

W:Sb

- Moderate to large wintering concentration of seabirds - October to May. Large concentrations of murres at ice edge in May.

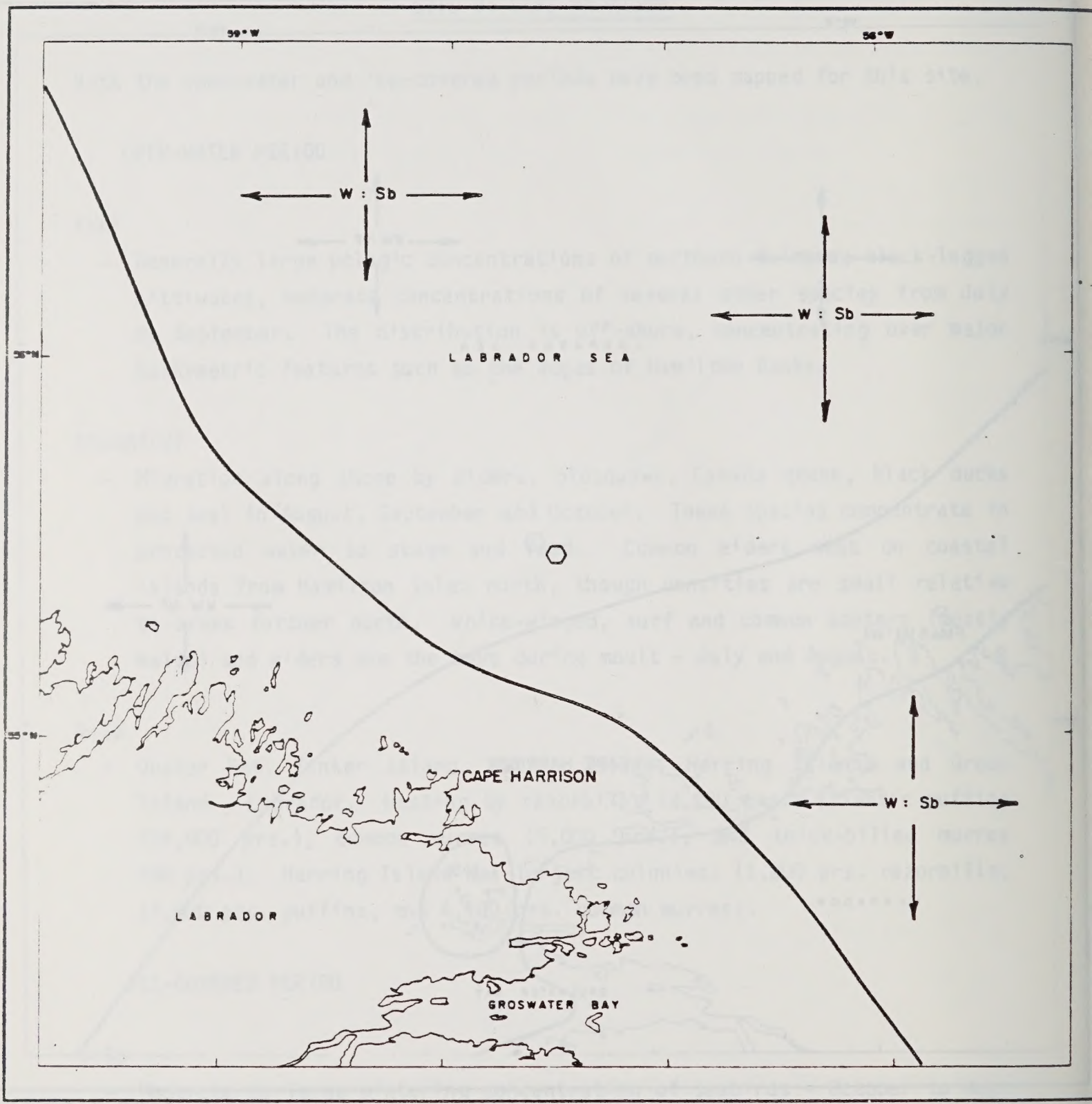
SEABIRDS



SITE 9 : CAPE HARRISON
OPEN - WATER PERIOD

FIG. B.62

SEABIRDS



SITE 9 : CAPE HARRISO
ICE- COVERED PERIOD

FIG. B.63

SITE 9: CAPE HARRISON

Both open-water and ice-covered periods have been mapped for this site.

OPEN-WATER PERIOD:

G:HR
- Harbour seals are found coastally; densities have not been determined.
- Whelping occurs in May and June.

G:GS
- Grey seals occur along the coast during the summer but do not breed or whelp in the area.
- Numbers are relatively small compared to areas further south.

Ms:HD
- Hooded seals migrate through the area in spring travelling northwards along the pack-ice in April and May.
- The return migration occurs in October - December.

G:RS
- Ringed seals are present in low numbers along the coast.

Ms:HS
- Harp seals migrate northwards through the area during April and May.
- The return migration occurs from October through December.
- Relatively small numbers of harp seal may remain along the Labrador coast during the summer.

G:W
- Small numbers of sei, fin, killer, minke, humpback, and blue whales travel along the Labrador coast during the summer.
- White-sided and white-beaked dolphins and harbour porpoise also occur along the coast in summer.

G,R:PW
- Pilot whales occur both along the coast and offshore from July through September; pod sizes range from 20 to 85 whales with greater densities found coastally. Calving occurs in August.

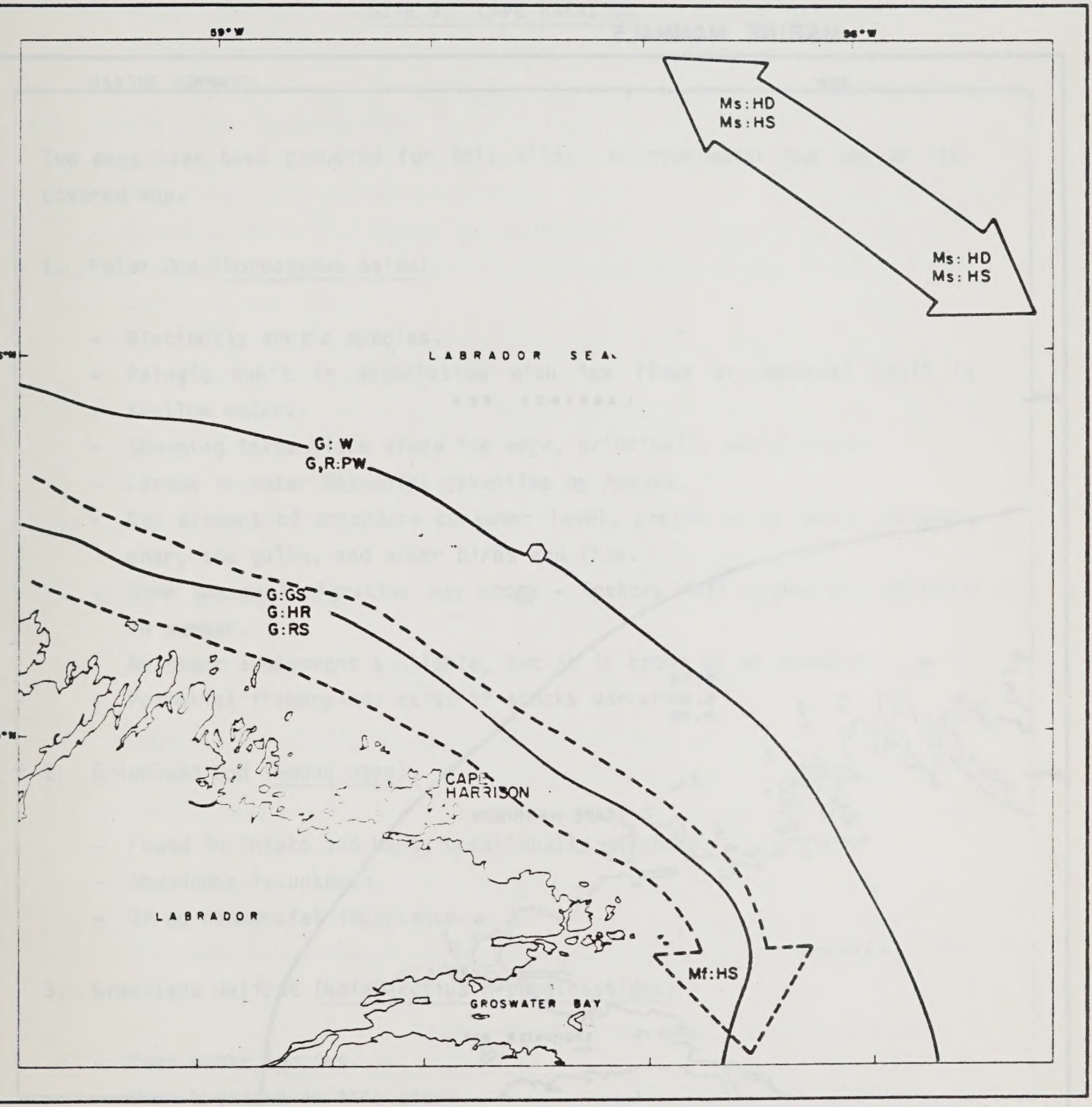
ICE-COVERED PERIOD:

G:HR
- Harbour seals are present but not abundant.
- Open-water areas (river mouths, tidal runs, etc.).

G:PB
- Relatively small numbers of polar bears are present hunting seals on the shifting pack ice.

R:RS
- Ringed seals occur in fast ice areas though densities are much lower than in arctic waters. Whelping also occurs earlier in April.

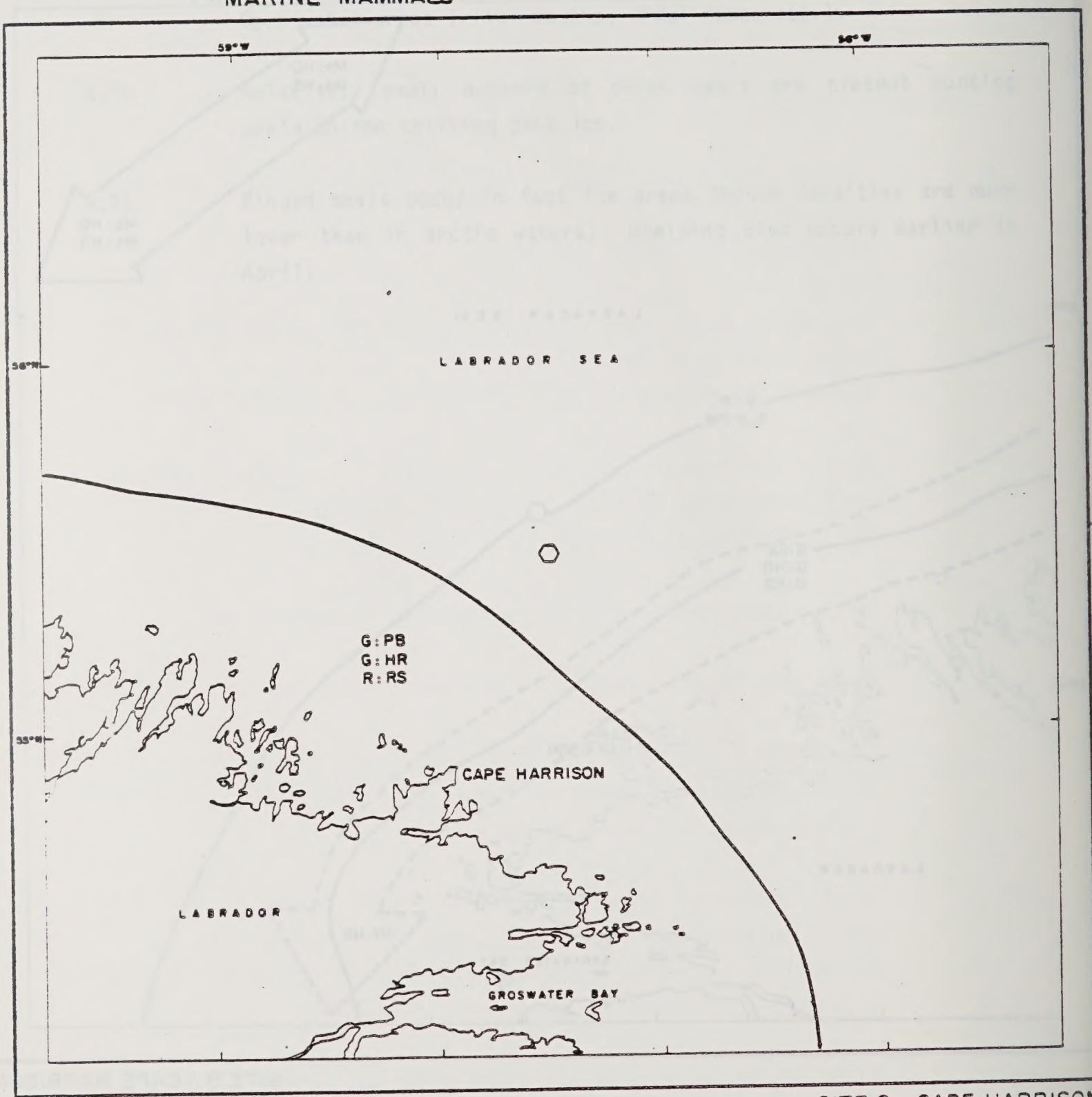
MARINE MAMMALS



SITE 9 : CAPE HARRISON
OPEN - WATER PERIOD

FIG. B.64

MARINE MAMMALS



SITE 9 · CAPE HARRISON
ICE-COVERED PERIOD

FIG. B. 65

FISHERY RESOURCES

SITE 9: CAPE HARRISON

MARINE SPECIES

Two maps have been prepared for this site: an open-water map and an ice-covered map.

1. Polar Cod (Boreogadus saida)

- Distinctly arctic species.
- Pelagic habit in association with ice floes or demersal habit in shallow water.
- Spawning takes place along ice edge, principally early winter.
- Larvae in water May-July; juveniles by August.
- Key element of secondary consumer level, preyed on by seals, belugas, char, sea gulls, and other birds and fish.
- Some seasonal migration may occur - inshore fall migration, offshore in summer.
- No stock assessment available, but it is known to be abundant.
- Potential fishery may exist if stocks warrant.

2. Greenland Cod (Gadus ogac)

- Found in inlets and bays, occasionally offshore.
- Abundance is unknown.
- Of no commercial importance.

3. Greenland Halibut (Reinhardtius hippoglossoides)

- Deep water species.
- Very abundant in this area.
- Spawns in winter. Larvae dispersed south by Labrador Current. Juveniles move offshore as they develop.
- Mature fish found furthest offshore (continental slope).

- Is fished predominantly by foreign offshore trawlers and has potential for increased fishery. Total Allowable Catch (1980) - 35,000 MT (Labrador - Grand Banks).

4. Greenland Shark (Somniosus microcephalus)

- Found near surface or along coasts during winter (often along ice edge).
- Moves to deeper water (200 m) during summer.
- Opportunistic feeder, but relies heavily on carrion, seals, halibut and salmon.
- Represents potential fishery (primarily for its oil).

5. Atlantic Halibut (Hippoglossus hippoglossus)

- Exhibits inshore/offshore seasonal migrations.
- Spawning information limited; possibly spring or summer. Juveniles move offshore as they develop.
- Distribution and abundance north of Hamilton Inlet unknown.

6. American Plaice (Hippoglossoides platessoides)

- Plentiful in this area, but at the northern extent of its range.
- Spawns during summer between 150 and 500 m. Eggs and larvae drift south with Labrador Current.
- Important prey for cod, halibut and Greenland sharks.
- Fished by trawl, gillnet and longlines. Average catches approximate 8000 MT. Stocks declining. Total Allowable Catch (1979) 6,000 MT (Labrador - northeastern Newfoundland).

7. Witch Flounder (Glyptocephalus cynoglossus)

- At northern extent of its range.
- Moves inshore in summer, offshore in winter.

- Spawns in deep water in spring. Information lacking on larvae and juveniles.
- Fished by trawl and seine. Catches declining since 1977. Total Allowable Catch (1980) - 17,000 MT.

8. Atlantic Cod (Gadus morhua)

- One of the most abundant species.
- Migrates inshore in summer and offshore in winter.
- Spawns in deep water in spring, but spawning is more intense north and south of this site.
- Eggs are buoyant.
- Most important commercial fish species in the Labrador area.
- Fished inshore (traps, gillnets, handline) as well as offshore (trawls, seines, and longlines).
- Stocks reduced due to fishing pressure.
- Total Allowable Catch (1980) 20,000 MT.

9. Redfish (Sebstes sp.)

- Two species present - S. mentella and S. marinus.
- At northern extent of range.
- Deep water inhabitant, migrates vertically.
- Spawns in fall; females retain eggs overwinter, releasing live young during next summer.
- Young stay in surface waters for sometime after birth.
- Exhibits slow growth rate.
- This site is important nursery ground.
- Was important fishery; stocks reduced by overfishing. Total Allowable Catch (1980) - 35,000 MT.

10. Grenadier (Coryphaenoides rupestris)

- Found in deep water.
- Exhibit inshore migration during late summer and fall, moves off into deep water mid-winter, possibly to spawn.

- Spawning information scarce; larvae are pelagic.
- Important food source of halibut.
- Object of fishery by Russians. Often taken as by-catch of Greenland halibut fishery. Commercial concentrations exist on Hamilton Bank.
- Spawning information limited.
- Rock grenadier (Coryphaenoides rupestris) also present in deep water.

11. Sculpins

- 9 species found in this area:
  - Arctic hookear (Artediellus uncinatus)
  - Arctic staghorn (Gymnocanthus tricuspis)
  - twohorn (Icelus bicornis)
  - spatulate (I. spatula)
  - fourhorn (Myoxocephalus quadricornis)
  - shorthorn (M. scorpius)
  - Arctic (M. scorpioides)
  - Nybelin's (Triglops nybelini)
  - mailed (T. murrayi)
- None of economic importance to Labrador coast.
- Information on spawning and larvae lacking. Eggs are demersal.

12. Herring (Clupea harengus harengus)

- At the northern limit of abundance.
- Spawn inshore (60-80 m) during August and September. Eggs are demersal.
- Very important food source for cod, hake, salmon, squid, sea birds, seals, and whales.
- May increase in economic value if stocks are sufficient.

13. Capelin (Mallotus villosus)

- Very important prey species, used by cod, salmon, flounders, herring, seals, and whales.
- Spawns on beaches starting mid-July or later. May spawn offshore as well. Eggs remain in gravel, time of hatching depends on water temperature.
- Important fishery, although catches are declining. Total Allowable Catch (1978) - 500,000 MT.
- Fished using purse seines, trawls, traps, and dipnets.

ANADROMOUS FISH

1. Arctic Char (Salvelinus alpinus)

- Runs to sea in spring to feed.
- Returns to rivers and streams in late summer/fall to spawn.
- Slow growing fish.
- Eggs incubate overwinter; smolts remain in rivers and lakes for 5-7 years before running to sea (150-200 mm length).
- Important food source for man, terns, loons, char and seals.
- Important to native fisheries; fished with gillnets.
- Important also for sportfishing.

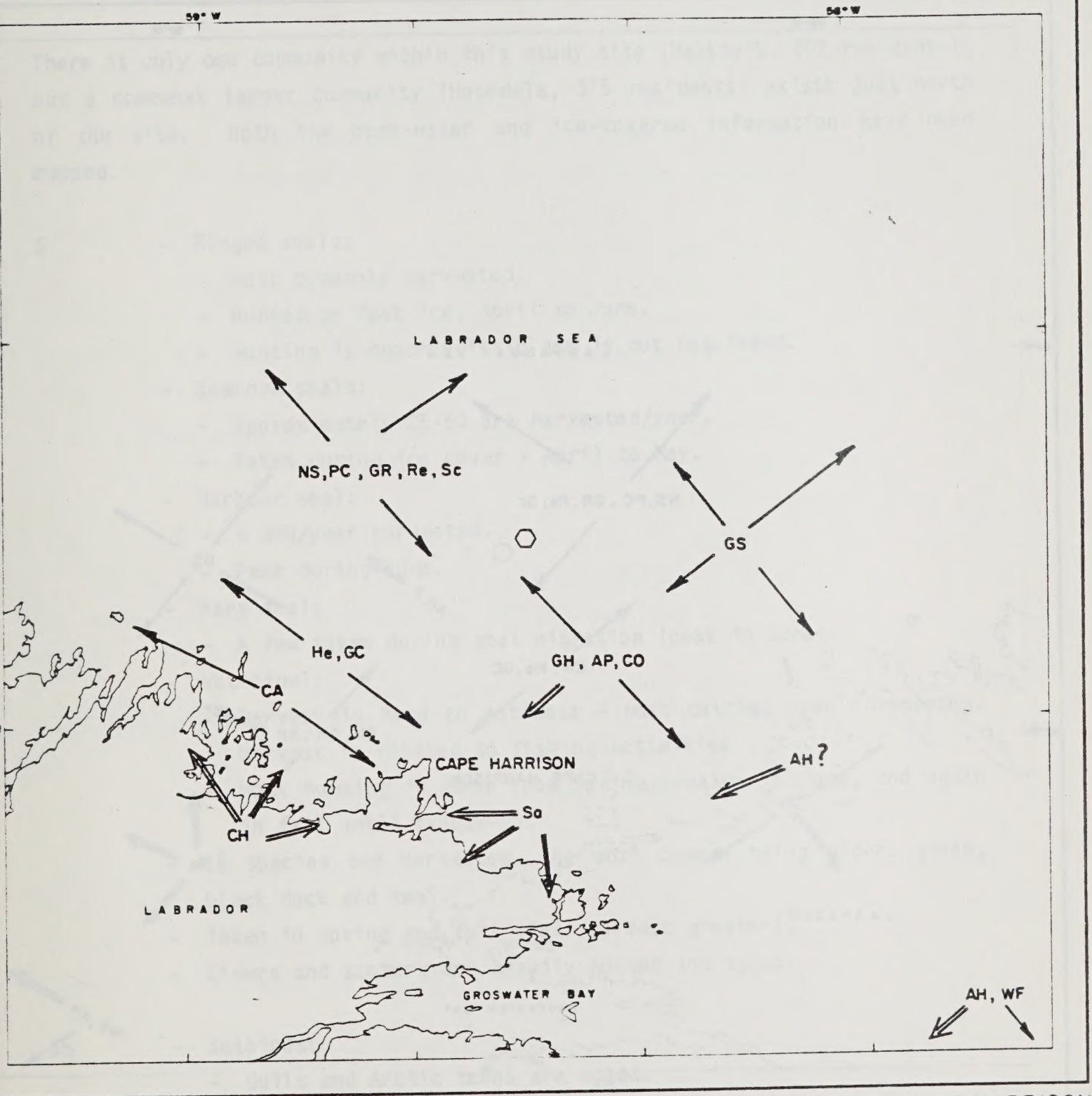
2. Atlantic Salmon (Salmo salar)

- Runs upstream during spring and fall. Spawns in fall.
- Young return to sea after three years.
- Exhibits long migrations at sea; fish from Labrador may migrate south to east coast of Canada, or north to Greenland.
- Very important to native fisheries and sportfishermen.

MISCELLANEOUS

1. Northern Shripm (Pandalus borealis)

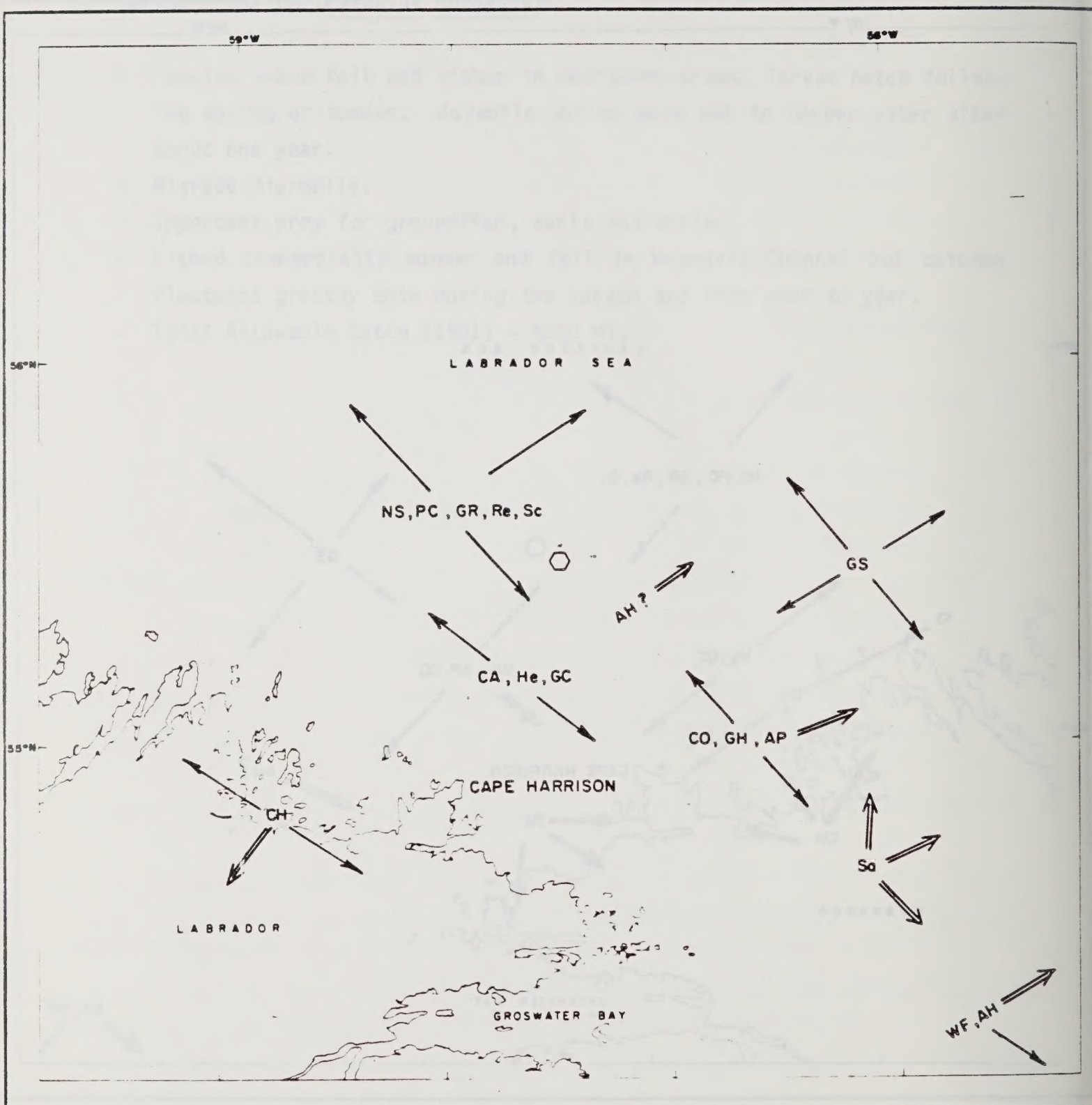
- Females spawn fall and winter in nearshore areas, larvae hatch following spring or summer. Juvenile shrimp move out to deeper water after about one year.
- Migrate diurnally.
- Important prey for groundfish, seals and whales.
- Fished commercially summer and fall in Hopedale Channel but catches fluctuate greatly both during the season and from year to year.
- Total Allowable Catch (1981) - 4000 MT.



SITE 9 CAPE HARRISON
OPEN-WATER PERIOD

FIG. B.66

FISHERY RESOURCES



SITE 9 : CAPE HARRISO
ICE-COVERED PERIOD

FIG. B.6

HUNTING AND FISHING

SITE 9: CAPE HARRISON

There is only one community within this study site (Makkovik, 292 residents), but a somewhat larger community (Hopedale, 375 residents) exists just north of the site. Both the open-water and ice-covered information have been mapped.

S
- Ringed seals:
  - Most commonly harvested.
  - Hunted on fast ice, April to June.
  - Hunting is opportunistic and is not regulated.
- Bearded seals:
  - Approximately 25-50 are harvested/year.
  - Taken during ice cover - April to May.
- Harbour seal:
  - < 300/year harvested.
  - Peak during June.
- Harp seal:
  - A few taken during seal migration (peak in June).
- Waterfowl:
  - Harvest is hard to estimate - most catches aren't reported. Harvest is related to fishing activities.
  - Most hunting is done from spring breakup to June, and again in fall until freeze-up.
- 16 species are harvested, the most common being eider, geese, black duck and teal.
- Taken in spring and fall (fall harvest greater).
- Eiders and scoters are heavily hunted and egged.

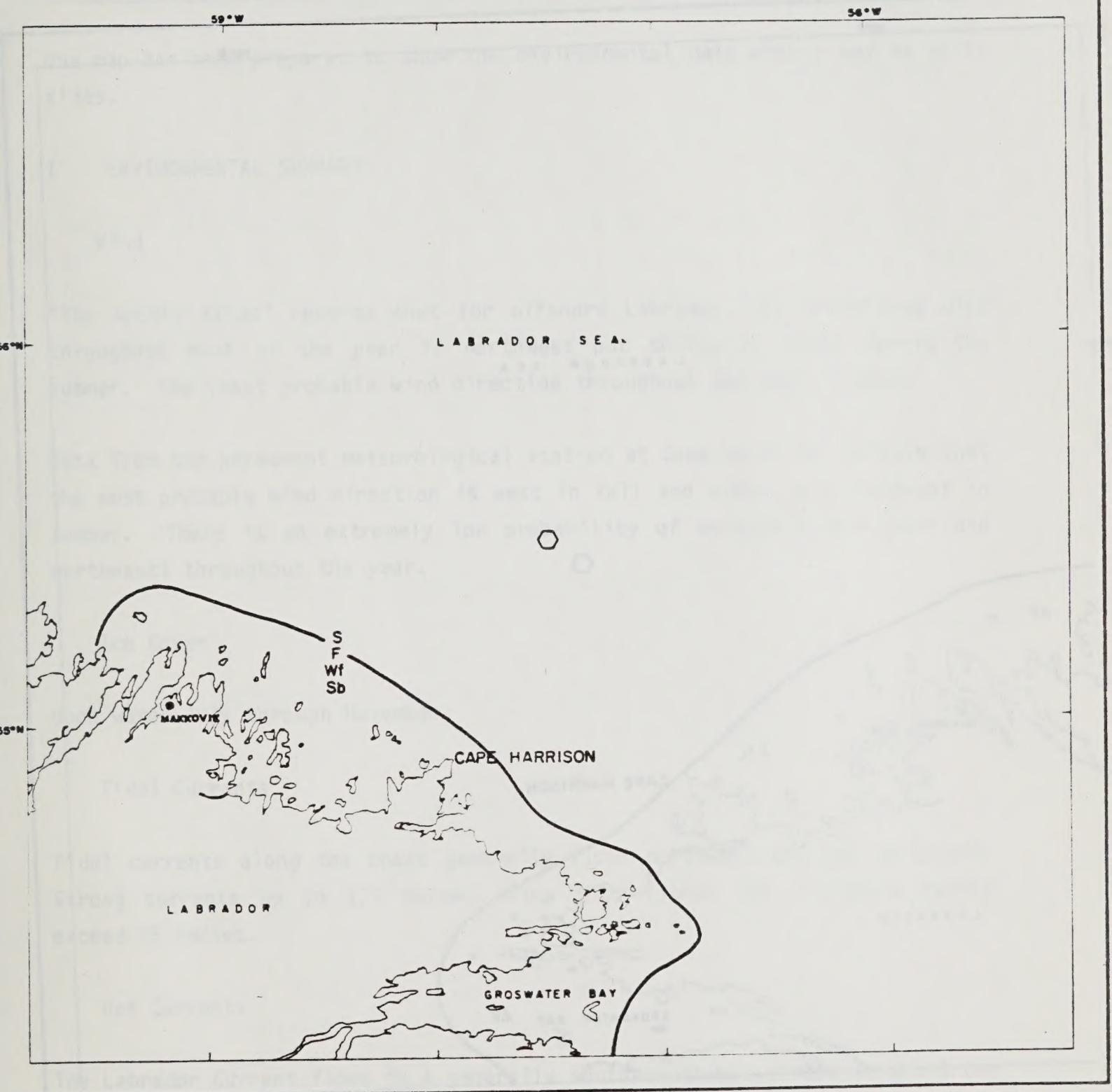
Sb
- Seabirds:
  - Gulls and Arctic terns are egged.
  - Jaegers and skua are hunted for food.
  - Murres are hunted and egged without restriction.

FISHERIES

Inshore
- Char, salmon, and cod primary species.
- Char and salmon can be taken by Inuit only.
- Cod fishing is declining.
- 783 metric tons of char and salmon taken per year.
- salmon - most important fish resource inshore.
  - Hopedale one of the best centers in Labrador.
- Char:
  - Almost all rivers contain char.
  - Peak fishing in late July to mid or late August.
  - Commercially caught in bays by gillnetting.
  - 10,000 kg/wk. taken.
- Cod:
  - Fished during ice-free season with cod traps and hand lines.
  - Fished in 20-40 m water.
  - Most is salted.
- Fish plants:
  - Plant is located at Makkovik.
  - Makkovik processed 83,000 lb. salmon and 9,000 lb. char in 1975.
  - The plant operates from June to November.
  - Hopedale is also a collecting station (28,000 lb. salmon and 2,000 lb. char (1975)).
- Flatfish becoming important to gillnetters and longliners.

Offshore
- Most fishing is by Newfoundlanders or foreign boats (15 nations).
- Primary species - cod, redfish, capelin, flatfish.
- Foreign boats in area during January to February with a few returning in fall.
- Cod is fished in winter, capelin in fall.

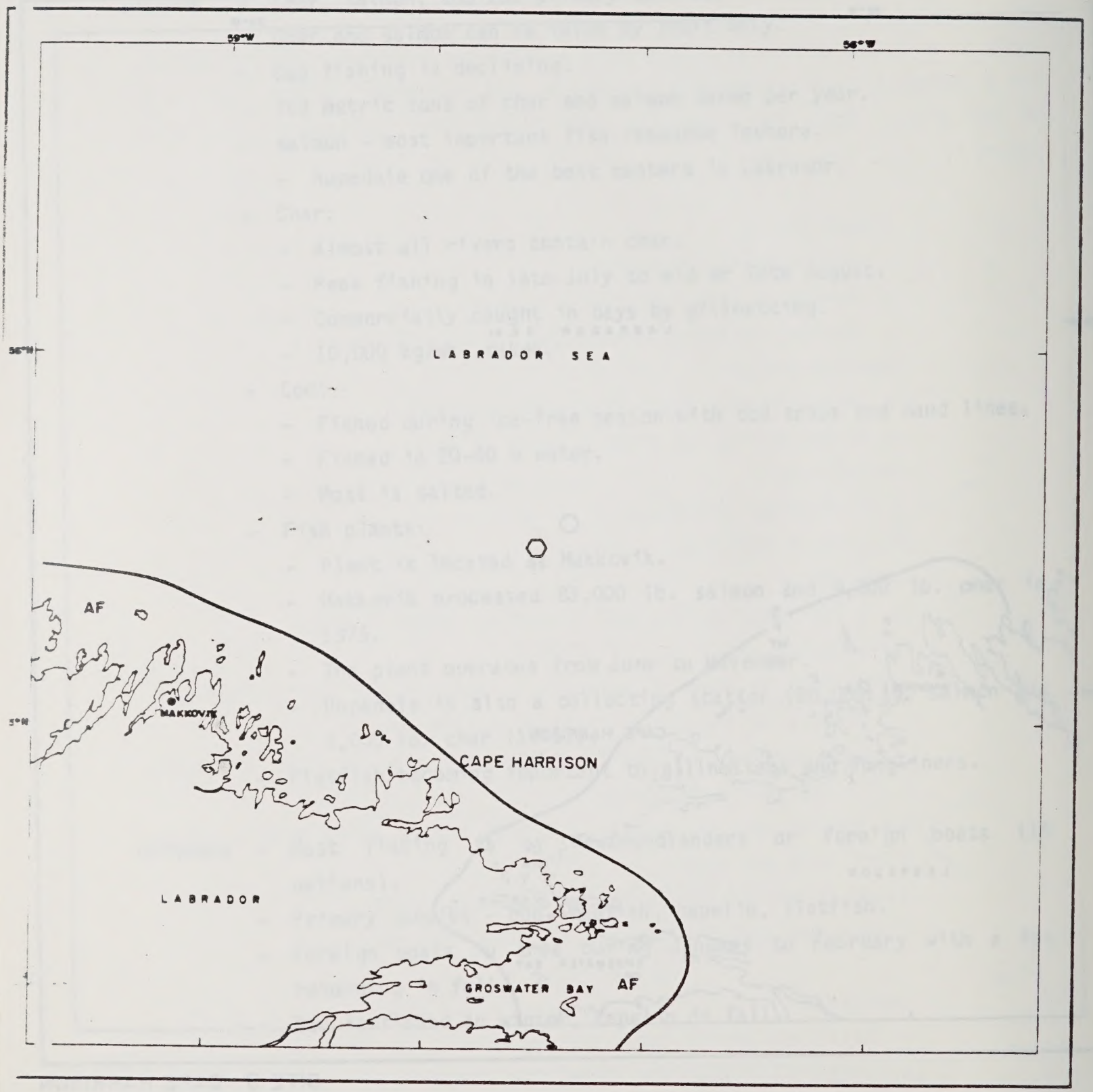
HUNTING AND FISHING



SITE 9 : CAPE HARRISON
OPEN - WATER PERIOD

FIG. B. 68

HUNTING AND FISHING



SITE 9 : CAPE HARRISON
ICE - COVERED PERIOD

HYPOTHETICAL SLICK MOVEMENT

SITE 9: CAPE HARRISON

One map has been prepared to show the environmental data with a key to spill sizes.

I ENVIRONMENTAL SUMMARY

Wind

"The Arctic Atlas" reports that for offshore Labrador, the prevailing wind throughout most of the year is northwest but shifts to south during the summer. The least probable wind direction throughout the year is east.

Data from the permanent meteorological station at Cape Harrison indicate that the most probable wind direction is west in fall and winter and northwest in summer. There is an extremely low probability of onshore winds (east and northeast) throughout the year.

Ice Cover

Open water July through November.

Tidal Currents

Tidal currents along the coast generally flood northward and ebb southward. Strong currents up to 175 cm/sec. flow into fjords but elsewhere rarely exceed 25 cm/sec.

Net Currents

The Labrador Current flows in a generally south-southwest direction along the eastern coast of Labrador. In the summer the current appears to be composed of three filaments each containing water from a different source. South of approximately 55° N latitude the filaments coalesce into two filaments. The

velocity inside the filaments seems to range from 15 to 40 cm/sec. Between filaments the velocity is generally less than 10 cm/sec. The exact location of each filament is quite variable, probably due to meterological phenomena.

II SURFACE SLICK

Trajectory

The site falls into what is generally the central filament of the Labrador Current just north of where the currents are thought to coalesce. From the point of coalescence the slick could follow either the nearshore or offshore current. Due to the very low probability of onshore winds the slick would be quite likely to continue to follow the Labrador Current either out into the Atlantic or perhaps, in the case of larger spills, to the coast of Newfoundland.

General

If a spill were to reach shore it would likely be spread a considerable distance by longshore currents.

30 m^3 - Surface extent is small relative to open water; unlikely to impact shore as a coherent slick.

300 m^3 - Significant relative to coastal features.

3,000 m^3 - Significant relative to coastal features but still small relative to North Atlantic.

30,000 m^3 - Surface extent is small relative to the North Atlantic. However, could spread for hundreds of kilometers if it came ashore on Labrador. Sufficient persistency to conceivably impact Newfoundland.

III WATER COLUMN CONCENTRATIONS

30-300 m^3 - Small relative to water mass dimensions.

30,000 m^3 - Significant relative to width of Labrador Current.

HYPOTHETICAL SLICK MOVEMENT

SITE 9 CAPE HARRISON

Spill Volume
30 m^3
300 m^3
3000 m^3
30000 m^3

Slick Diameter
1.8 km
5.6 km
18 km
45 km

Diameter 100 ppb Contamination
4.1 km
13.0 km
41 km
130 km

FIG.B.70